Journal of the Royal Society of Arts

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FORTHCOMING MEETINGS

WEDNESDAY, 11TH MARCH, AT 2.30 p.m. "*The High Paddington Scheme*", by Sergei Kadleigh, A.R.I.B.A. L. Dudley Stamp, C.B.E., D.Lit., D.Sc., Professor of Social Geography, London School of Economics and Political Science, will preside. (The paper will be illustrated with lantern slides.) An architectural model of the Scheme, which is a proposal to construct a town for 8,000 inhabitants over sidings at Paddington Station Marshalling Yard, will be displayed in the Society's Library from Monday, March 9th to Friday, March 13th, from 10 a.m. to 5.30 p.m. (On Wednesday to 6 p.m.)

THURSDAY, 12TH MARCH, AT 5.15 p.m. COMMONWEALTH SECTION. "*Social Changes in the Western Pacific*", by Raymond W. Firth, M.A., Ph.D., F.B.A., Professor of Anthropology, University of London. Sir Keith Hancock, M.A., Litt.D., F.B.A., Professor of British Commonwealth Affairs, University of London, and Director, Institute of Commonwealth Studies, will preside. (The paper will be illustrated with lantern slides. Tea will be served from 4.30 p.m.)

WEDNESDAY, 18TH MARCH, AT 2.30 p.m. "*The Contemporary Role of Industrial Standards*", by H. A. R. Binney, C.B., Director and Secretary, British Standards Institution. Sir Graham Cunningham, K.B.E., Chairman, Shipbuilding Advisory Committee, will preside.

TUESDAY, 24TH MARCH, AT 5.15 p.m. COMMONWEALTH SECTION. "*Making Films in and for the Colonies*", by W. Sellers, O.B.E., Producer, Colonial Film Unit. The Honble. Anthony Asquith will preside. (The paper will be illustrated with films. Tea will be served from 4.30 p.m.)

WEDNESDAY, 25TH MARCH, AT 2.30 p.m. "*The Collection of Folklore in England*", by Peter Opie. The Right Honble. Lord Raglan, F.S.A., Past-President, Folklore Society, will preside. (The paper will be illustrated with exhibits, lantern slides and recordings.)

FRIDAY, 27TH MARCH, AT 5.15 p.m. COMMONWEALTH SECTION. "*The Kitimat Hydro-Electric Power Development Scheme*", by F. L. Lawton, P.Eng., Fel. A.I.E.E., M.E.I.C., M.A.S.C.E., Chief Engineer, Power Department, Aluminium Laboratories, Ltd., Montreal. (Tea will be served from 4.30 p.m.)

THE ALBERT MEDAL

The Council are now considering the award of the Albert Medal of the Royal Society of Arts for 1953. They therefore invite Fellows of the Society to forward to the Secretary the names of such men of high distinction as they think worthy of this honour. The Medal was struck to reward "distinguished merit in promoting the Arts, Manufactures and Commerce", and has been awarded as follows in previous years:

1864 Sir Rowland Hill
1865 His Imperial Majesty Napoleon III
1866 Michael Faraday
1867 Sir W. Fothergill Cooke and Sir Charles Wheatstone
1868 Sir Joseph Whitworth
1869 Baron Justus von Liebig
1870 Vicomte Ferdinand de Lesseps
1871 Sir Henry Cole
1872 Sir Henry Bessemer
1873 Michel Eugene Chevreul
1874 Sir C. W. Siemens
1875 Michael Chevalier
1876 Sir George B. Airy
1877 Jean Baptiste Dumas
1878 Sir Wm. G. (afterwards Lord) Armstrong
1879 Sir William Thomson (afterwards Lord Kelvin)
1880 James Prescott Joule
1881 Prof. August Wilhelm Hofmann
1882 Louis Pasteur
1883 Sir Joseph Dalton Hooker
1884 Captain James Buchanan Eads
1885 Sir Henry Doulton
1886 Samuel Cunliffe Lister (afterwards Lord Masham)
1887 HER MAJESTY QUEEN VICTORIA
1888 Professor Hermann Louis Helmholtz
1889 John Percy
1890 Sir William Henry Perkin
1891 Sir Frederick Abel, Bt.
1892 Thomas Alva Edison
1893 Sir John Bennet Lawes, Bt., and Sir Henry Gilbert
1894 Sir Joseph (afterwards Lord) Lister
1895 Sir Isaac Lowthian Bell, Bt.
1896 Professor David Edward Hughes
1897 George James Simons
1898 Professor Robert Wilhelm Bunsen
1899 Sir William Crookes
1900 Henry Wilde
1901 HIS MAJESTY KING EDWARD VII
1902 Professor Alexander Graham Bell
1903 Sir Charles Augustus Hartley
1904 Walter Crane
1905 Lord Rayleigh
1906 Sir Joseph Wilson Swan
1907 The Earl of Cromer
1908 Sir James Dewar
1909 Sir Andrew Noble
1910 Madame Curie
1911 The Hon. Sir Charles Algernon Parsons
1912 The Right Hon. Lord Strathcona and Mount Royal
1913 HIS MAJESTY KING GEORGE V
1914 Chevalier (afterwards Marchese) Guglielmo Marconi
1915 Sir Joseph John Thomson
1916 Professor Elias Metchnikoff
1917 Orville Wright
1918 Sir Richard Tetley Glazebrook
1919 Sir Oliver Joseph Lodge
1920 Professor Albert Abraham Michelson
1921 Sir J. Ambrose Fleming
1922 Sir Dugald Clerk
1923 Major-General Sir David Bruce and Colonel Sir Ronald Ross
1924 H.R.H. THE PRINCE OF WALES
1925 Lieut-Colonel Sir David Prain
1926 Professor Paul Sabatier
1927 Sir Aston Webb
1928 Sir Ernest (afterwards Lord) Rutherford
1929 Sir J. Alfred Ewing
1930 Professor Henry E. Armstrong
1931 H.R.H. THE DUKE OF CONNAUGHT AND STRATHEARN
1932 Frank (now Sir Frank) Brangwyn
1933 Sir William Llewellyn
1934 Sir Frederick Gowland Hopkins
1935 Sir Robert A. Hadfield, Bt.

1936 The Earl of Derby
1937 Lord (now Viscount) Nuffield
1938 HER MAJESTY QUEEN MARY
1939 Sir Thomas H. Holland
1940 John A. Milne
1941 President Franklin D. Roosevelt
1942 Field-Marshal J. C. Smuts
1943 Sir John Russell
1944 Sir Henry Tizard
1945 Winston Spencer Churchill
1946 Sir Alexander Fleming and Sir Howard Florey
1947 Sir Robert Robinson
1948 Sir William Reid Dick
1949 Sir Giles Gilbert Scott
1950 Sir Edward Appleton
1951 HIS MAJESTY KING GEORGE VI
1952 Sir Frank Whittle

THE SWINEY PRIZE FOR A WORK ON JURISPRUDENCE

The Council give notice that the next award of the Swiney Prize will be made in January, 1954, the one hundred and tenth anniversary of the testator's death. Dr. Swiney died in 1844, and in his will he left a sum of money to the Royal Society of Arts for the purpose of presenting a prize, on every fifth anniversary of his death, to the author of the best published work on Jurisprudence. The Prize is a cup of the value of £100 and money to the same amount.

The Prize is offered alternately for Medical and General Jurisprudence, but if at any time the Selection Committee is unable to find a work of sufficient merit in the class which has been announced, it is at liberty to recommend a book belonging to the other class. On the last occasion of the award (1949) the Prize was awarded for Medical Jurisprudence. It is, therefore, offered on the present occasion for General Jurisprudence.

Any person desiring to submit his own work, or to recommend the work of any other person for the consideration of the Judges, should send a copy of the book to the Secretary not later than 30th November, 1953.

The following is a list of former recipients:

1849 J. A. Paris, M.D. and J. Fonblanque, for their work, "Medical Jurisprudence".
1854 Leone Levi, for his work, "The Commercial Law of the World".
1859 Dr. Alfred Swayne Taylor, F.R.S., for his work, "Medical Jurisprudence".
1864 Henry Sumner Maine (afterwards K.C.B.), D.C.L., for his work, "Ancient Law".
1869 William Augustus Guy, M.D., for his "Principles of Forensic Medicine".
1874 The Right Hon. Sir Robert Joseph Phillimore, D.C.L., for his "Commentaries on International Law".
1879 Dr. Norman Chevers, for his "Manual of Medical Jurisprudence of India".
1884 Sheldon Amos, M.A., for his work, "A Systematic View of the Science of Jurisprudence".
1889 Dr. Charles Meymott Tidy, F.C.S., for his work, "Legal Medicine".
1894 Thomas Erskine Holland (afterwards knighted), K.C., D.C.L., for his work, "The Elements of Jurisprudence".

1899 Dr. J. Dixon Mann, F.R.C.P., for his work, "Forensic Medicine and Toxicology".
1904 Sir Frederick Pollock, Bt., and Professor F. W. Maitland, for their work, "The History of English Law before Edward I".
1909 Dr. Charles Mercier, F.R.C.P., F.R.C.S., for his work, "Criminal Responsibility".
1914 John W. Salmond, K.C., for his work, "Jurisprudence".
1919 Dr. Charles Mercier, F.R.C.P., F.R.C.S., for his work, "Crime and Criminals".
1924 Professor Sir Paul Vinogradoff, F.B.A., for his work, "Outlines of Historical Jurisprudence".
1929 Professor Sydney Smith, M.D., for his work, "Forensic Medicine".
1934 Professor Sir William S. Holdsworth, K.C., for his work, "A History of English Law".
1939 Professor John Glaister, M.D., D.Sc., F.R.S.E. and Professor J. C. Brash, M.C., M.A., M.D., F.R.S.E., F.R.C.S.(Ed.), for their work, "Medico-Legal Aspects of the Ruxton Case".
1944 Carleton Kemp Allen, M.C., M.A., D.C.L., for his work, "Law in the Making".
1949 Professor John Glaister, J.P., M.D., D.Sc., F.R.S.E., for his work, "Medical Jurisprudence and Toxicology".

INDUSTRIAL ART BURSARIES COMPETITIONS

1952 COMPETITION

At the request of the Council, the Industrial Art Bursaries Board again organized a Competition in 1952, and Bursaries of £150 were offered for the design of Carpets; Domestic Electrical Appliances; Domestic Gas Appliances; Domestic Solid-Fuel-Burning Appliances; Dress Textiles; Electric-Light Fittings; Footwear; Furnishing Textiles; Furniture; Men's Wear Fabrics; P.V.C. Plastics Sheeting; Laminated Plastics, and Wall-paper. The Sir Frank Warner Memorial Medal was also offered for the best design in the Carpet, Dress Textiles, Men's Wear Fabrics, and Furnishing Textiles Sections.

The Competition was open to full-time or part-time students between the ages of 17 and 30 of art, architectural, technical or other colleges or schools approved by the Society, and in the Domestic Gas and Domestic Solid-Fuel-Burning Appliances Sections eligibility was extended to include young draughtsmen, clerks or other similar persons engaged in those industries, provided that they were recommended as having sufficient ability to compete in a national competition by a responsible officer of the industry concerned. In all, 233 candidates, from 64 schools and industrial establishments, entered the Competition; this compares with 156 candidates in 1951, 189 in 1950 and 140 in 1949, in which years the numbers of schools represented were 45, 38, and 42 respectively.

Candidates were required, as in the Competition for 1951, both to undergo a Set Test, carried out under invigilation over a period beginning on the 3rd November, 1952, arranged by their schools, and also to submit Examples

of Work, chosen from the work done by them in the ordinary course of their studies since 1st September, 1951.

As in the past the Council's purpose in arranging this Competition was to enable successful candidates to broaden their knowledge and experience by travel abroad and the study of foreign design, or in certain cases to obtain art training or industrial experience in this country. The success of the tours made by Bursary winners depends largely upon their meeting manufacturers and industrial designers in the countries visited, and in past years many people in this country have kindly given assistance by providing helpful introductions. In this connection the Bursaries Board would be grateful to hear from Fellows who may be able to provide help to these students when abroad.

The Council desire to express their thanks to all those who have assisted and advised on the conduct of the Competitions, particularly the firms, organizations and individuals who generously subscribed towards the cost of the Bursaries, the Juries for their voluntary services, and the Principals of the 64 schools represented for their co-operation.

Awards

The Council, adopting the recommendations of the Industrial Art Bursaries Board based on the reports of the Juries, have awarded Bursaries amounting in value to £2,225. This compares with a total of £1,750 awarded in 1951. The following Awards and Commendations have been made in connection with the 1952 Competition:

DOMESTIC ELECTRICAL APPLIANCES

Bursary** (£150): **Mr. Geoffrey Gale (L.C.C. Central School of Arts and Crafts: age 22)

Commended: Mr. John Wilfred Cooper (L.C.C. Central School of Arts and Crafts: age 23)

ELECTRIC-LIGHT FITTINGS

Bursary** (£150): **Mr. Leonard Summers* (Birmingham College of Arts and Crafts: age 19)

Commended: Mr. Ronald William Saxby (South-East Essex Technical College and School of Art: age 17); ***Miss Jean Challis*** (Kingston School of Art: age 20); ***Mr. William Bernard Holdaway*** (Kingston School of Art: age 18); ***Mr. Alan Henry Tilbury*** (Kingston School of Art: age 17)

DOMESTIC GAS APPLIANCES

Bursary**: (£150) **Mr. Colin Reginald Cheetham (L.C.C. Central School of Arts and Crafts: age 26)

DOMESTIC SOLID-FUEL-BURNING APPLIANCES

Bursaries** (£150 and £100 respectively): **Miss Josephine Ann Matthews*

*Also awarded Associate Membership of the Society.

(Kingston School of Art: age 20); *Mr. William Bernard Holdaway** (Kingston School of Art: age 18)

Commended: Mr. James Scott Smith (L.C.C. Central School of Arts and Crafts): age 24); *Mr. William Easton Wren* (a draughtsman in the drawing office of Messrs. Lane & Girvan, Ltd., Bonnybridge: age 26)

CARPET

*Bursary (£150): Mr. Raymond Dennis Portman** (Kidderminster School of Science and Art: age 17)

Commended: Mr. Lawrence Avery (Northern Polytechnic, London, N.7: age 28); *Miss Ruby Mackie* (Kidderminster School of Science and Art: age 20)

DRESS TEXTILES

Bursaries (£150 each): Miss Ann Hilton Cutbill (L.C.C. Central School of Arts and Crafts: age 23); *Miss Jacqueline Needham** (Coventry School of Art: age 18); *Miss Ursula Marion White** (L.C.C. Central School of Arts and Crafts: age 19)

Commended: Miss Edith Florence Gash (Mansfield School of Art: age 18); *Mr. David Maxwell Hide* (Edinburgh College of Art: age 19)

MEN'S WEAR FABRICS

Bursaries (£75 each): Miss Barbara Gordon Batt (Brighton College of Art and Crafts: age 21); *Miss Rhoda Jean Hagg** (Norwich City College and Art School: age 20)

Commended: Miss Gillian Gordon Batt (Brighton College of Art and Crafts: age 21); *Mr. Terence Anthony Gorman* (L.C.C. Hammersmith School of Art and Crafts: age 26); *Mr. Brian Joseph Lobell* (Royal Technical College, Salford: age 17); *Miss Mary Middleton* (L.C.C. Central School of Arts and Crafts: age 21); *Miss Patricia Mary Nuttall* (School of Art, Blackburn: age 19)

FURNISHING TEXTILES

Bursaries (£150 and £100 respectively): Miss Mary Middleton (L.C.C. Central School of Arts and Crafts: age 21); *Mr. Michael John McInerney* (Brighton College of Art and Crafts: age 24)

Commended: Mr. Anthony Noel Lintott (Brighton College of Art and Crafts: age 22)

LAMINATED PLASTICS

*Bursary (£150): Mr. Roland Parnell Whiteside** (Kingston School of Art: age 20)

FOOTWEAR

*Bursary (£150): Miss Gaybrielle Vernon Stephen Wilkins** (Thanet School of Arts and Crafts: age 18)

*Also awarded Associate Membership of the Society.

Commended: Mr. Keith Ernest Wilmot (Leicester College of Technology: age 24); *Miss Patricia June Austin* (Thanet School of Art and Crafts: age 18)

FURNITURE

*Bursaries (£150 and £75 respectively): Mr. Donald Raymond Pedel** (High Wycombe College of Further Education: age 19); *Mr. Martin Cunningham Grierson** (L.C.C. Central School of Arts and Crafts: age 19)

Commended: Mr. John Sutherland Boath (Edinburgh College of Art: age 20); *Mr. Donald James Cooke* (Birmingham College of Art and Crafts: age 19); *Mr. Glyn Lewis Davies* (Birmingham College of Art and Crafts: age 23); *Mr. Michael John Knott* (Birmingham College of Art and Crafts: age 18); *Miss Pamela Elizabeth Robinson* (Kingston School of Art: age 18); *Mr. Peter Taylor* (Leicester College of Art: age 25)

WALL-PAPER

Commended: Mr. Dennis Roger Limbrick (West Sussex College of Art and Crafts: age 19); *Miss Kathleen Mary Veevers* (Royal College of Art: age 21)

The Sir Frank Warner Memorial Medal: Miss Ursula Marion White (L.C.C. Central School of Arts and Crafts: age 19)

Publication of Report

Full details of the 1952 Competition will be contained in the annual Report on the Competition which, following last year's practice, will be published together with the Particulars of the next Competition early in April. This Report will contain particulars of the tests set in each section, the names of the winning and commended candidates, the reports and composition of the Juries, and a summary of the uses made of Bursaries in 1952 by previous Bursary winners. Illustrations of most of the winning designs will also be included and it is intended to publish some of these, with the general comments on the Competition made by the Bursaries Board, in the *Journal.*

Exhibition

An exhibition of the winning and commended designs in the 1952 Competition will be held at the Royal Society of Arts from Monday, 11th May to Friday, 22nd May, 1953, and will be open to the public from 10 a.m. to 5.30 p.m. on Mondays to Fridays, and from 10 a.m. to 12.30 p.m. on Saturday, 16th May.

Included in the exhibition will be the reports prepared by Bursary winners on the uses made of their bursaries in 1952.

ARRANGEMENTS FOR 1953 COMPETITION

The Council have decided to hold a further Competition in 1953, which will be organized on the same lines as that in 1952. Particulars of this Competition will, as stated above, be published together with the Report on the 1952 Competition early in April, and the list of sections to be included will then be announced in the *Journal.*

*Also awarded Associate Membership of tne Society.

USE AND ABUSE OF FUELS

A paper by

W. E. P. JOHNSON, A.F.C., C.P.A.

Managing Director, Power Jets (Research & Development), Ltd., read on Wednesday, 14th January, 1953, with F. E. Simon, C.B.E., M.A., Ph.D., F.R.S., Professor of Thermodynamics, University of Oxford, in the Chair

THE CHAIRMAN: I think it is hardly necessary to emphasize the importance of the subject we are going to discuss to-day. The general public certainly takes a great interest in it—as you can see from the rather pathetic discussions in the correspondence columns of our newspapers—but they have hardly enough information to form accurate opinions. The whole problem is very complex; from whatever side you look, it seems to have a different aspect.

Our lecturer has been concerned with one such aspect throughout his whole life; you may know that he was one of the closest associates of Sir Frank Whittle, and the development of the turbine aero-engine owes a great deal to him. It was his handling of the patents for this development that is largely responsible for the fact that we can now reap the fruits of fundamental development carried out in this country—and I am afraid that that is something which has not happened very frequently in the last fifty or hundred years. Our lecturer is, therefore, very well used to thinking in terms of the national economy as a whole, and we are looking forward to what he has to tell us.

The following paper was then read:

THE PAPER

Any discussion on the uses and abuses of fuel presupposes that we know what fuel is. This sounds elementary but the word covers far more than the average dictionary would lead us to believe. Fuel—material for fire—does not really get us very far and therefore I feel I must give you my own definition, not for it to withstand close scientific scrutiny but simply so that we shall know what this lecture is all about. Fuel then, for the purposes of this lecture, means a substance which reacts with another or others to release energy. You will see that this is a fairly wide definition and includes such things as food, saltpetre, oxygen and other things which are not normally thought of as fuel, as well as the obvious fuels like coal, marsh gas, etc. You will notice that I have said nothing so far about nuclear fission. This falls outside my definition because it involves a substance which reacts in and by virtue of the presence of another substance, but not with it. Its energy is released in the course of transmutation. Obviously, however, in any discussion of fuel in its broadest sense one must talk about nuclear fission since nuclear energy is going to replace in many cases energy derived from fuel. I will therefore return to the subject of nuclear fission later on.

Just as my definition of fuel was wide, my approach to the whole subject is going to be on the broadest possible lines. I do not propose to deal with the relatively obvious aspects of fuel economy, such as those which concern the physical conservation of coal, for example, by preventing loss by improvident mining or the consumption of food by pests, important as both these matters are. Fuel economy may relate to the process of conversion of fuel into energy which I shall call functional economy, this would also cover the thrifty use of energy when released. The other type of economy I shall call absolute economy which is a reduction in the use of fuel by refraining from using it at all.

It is a fair generalization to say that all fuel is an accumulation of solar energy. Indeed the sun is the original source of all our usable energy, be it energy of fuel, or wind or water. In the case of fuel, however, we are considering something stored or bottled up by nature for use later. It is this basic fact which so clearly points the need for economy. When we use mineral fuels for our activities we are drawing on capital savings, not living on revenue earnings. It is already disquietingly apparent that the fuel bank is getting a little uneasy about our drawings, and I hope to show why later on. The merely statistical case, for example, of the known amount of coal under the United Kingdom is terrifying. Some comfort is to be derived from the fact that there is a happy geological suspicion that the word "known" is a very limiting qualification, but it is quite certain that all the easily accessible coal is known so that even if there be another 1,000 years of coal under us instead of say 200 years, the process of getting it will make it an expensive luxury. Much the same kind of statement could be made of oil although very differently in degree. Of food, you are as familiar as I am, with the pessimistic prospect of a world shortage although food, unlike coal and oil, is largely a revenue rather than a capital consumption.

Of other possible fuels, few have been seriously sought or considered and I shall touch on these later. The case for economy in this lecture is therefore taken as self-evident. Let us examine more closely what this economy entails. It can be said at the outset that fuel economy involves heavy capital outlay. The question is whether we can afford not to invest large sums and divert huge industrial resources to reduce the expenditure of our vital capital, for that is what is meant by fuel economy. It is not suggested that we shall ever avoid some expenditure of our vital capital; but it is strongly suggested that we may have to learn to replace the use of fuel by direct—therefore revenue—solar energy, to the maximum practicable extent. It is perhaps useful to outline one or two ways in which this might be done. The ordinary hydro-electric system is the most obvious example of direct conversion of solar into useful energy physically. Wind-power is in some places another useful method. Heat energy, concentrated by reflector systems can (subject to cost) also locally supply useful quantities of energy. A virtually undeveloped field, in which many branches of science will need to be co-ordinated for success, is the use of solar energy to synthesize more quickly than in nature, fuels of useful quantity and calorific value (or quality and nutritional value), for example photochemically or photo-biochemically. Such projects are, in effect, concerned to find "accumulators".

They are analogous to the storage of electricity: they do not create energy any more than fuel creates it. But they may replace part of the world's fuel consumption.

I should like here to quote a short passage from *Engineering* for 21st November, 1952, which reads: "The production of large amounts of power by burning wood is in principle possible. To produce 10,000 Kw. with a power station having an overall efficiency of 32 per cent would require 20 square kilometres of forest". The writer of that passage indicated that it involves a certain optimism as to the yield of timber to be expected continuously. This reference is in essence a reference to a possibility of storing solar energy by accumulating it in the form of trees; it therefore comes under the heading of photobiochemical synthesis.

A lump of coal, a gallon of oil, each is an accumulation of energy by reference to the oxygen with which it could be made to react and liberate heat. Oxygen, by reference to the coal or oil, is equally a fuel: its ubiquity should not blind us to this fact. Sulphur, carbon, and saltpetre are each fuels by reference to the other two, for they react together as gunpowder to release energy. Even water is a fuel, albeit a highly inconvenient one, by reference for example to strong sulphuric acid or metallic sodium.

I hope that this very long and somewhat diffuse preamble will have conditioned your minds to think of fuels as a class of substances which, by reference to other substances, act as the "doers" of nature. They enable you to move your muscles to breathe as you sit here, whilst you slowly burn your lunch with the oxygen in the room. They burned at an enormously great disadvantage in propelling the transport which brought us together. They are at this moment burning under a boiler to cause these lights to keep you awake. They were vital in the manufacture of your clothes, this furniture, the paper I am reading from. And we are, collectively, burning far too much to leave to our not too remote descendants the same amenities. So now to the question of economy.

Let me say at once that I do not know how we can economize in fuel either functionally or absolutely without, first, large capital investment, and second, a rejection of some of the household gods that we worship and the throwing overboard of a number of superstitions and sentimentalities.

What I do know is this: that the factors making for inefficient fuel consumption are well known and in a large degree remediable. A few picturesque examples may be helpful. I am going to adopt my own terminology here, and talk of "inefficiencies" rather than the smug-sounding "efficiencies" of this and that. I think it brings home the point more.

The ordinary steam locomotive has an inefficiency, under average conditions, of about 95 per cent. Of every 100 tons of coal cut, raised, cleaned, and carried to fill a locomotive tender, 95 are thrown away uselessly and in part harmfully. This figure does not include the coal used to get and carry the coal.

The ordinary electrical power station has an average inefficiency of about 79 per cent or so: the best power station, at its best, just about 69 per cent. If you stand on Westminster Bridge until 100 barge-loads of coal have gone up-river beneath you, be sure that at least 75 of them will be thrown back into

the river or the already polluted atmosphere—and the coal has been mined, trucked, shipped, and navigated down the North Sea, barged and towed up-river, so as to suffer that fate.

We go on building ordinary steam power stations. In only one or two cases are they so built that some of their waste heat, instead of just raising the temperature of a river by a degree or so, can be piped off and used.

Need I enlarge on open coal fires? I love them as we all do. I know that this is because I am conditioned to love them, and that my foreign cousins, in the ratio of probably twenty or thirty of them to one of me, do not. I further know that my cousins can and do keep clean and warm on less fuel per year than I buy per month. Lastly, I know that I cannot afford to indulge my purely acquired predilection for this hopelessly inefficient survival of the Saxon era.

The petrol engine as we know and commonly use it, has an inefficiency averaging about 73 per cent. With petrol at 4*s*. 4*d*. a gallon, this means, of course, that a car engine throws money out of your pockets, in the form of useless heat, to the tune of, let us say, 3*s*. 2*d*. for every gallon bought. The wastage of fuel is the gain of the tax-gatherer—but not, I submit, of the National economy.

The Diesel engine is about the best type of heat engine (other than the human or animal engine) in common use. In good cases we only need to afford an inefficiency of some 65–75 per cent to operate it, the exact amount depending on the engine itself, its duty and whether we run it steadily within a specified and quite wide range of power.

I speak either from bias, personal conviction, or information received when I say that the gas turbine can easily surpass any existing machine in reducing inefficiency, if properly designed, and equipped for a particular duty. It has not yet done so (although examples are running which prove my contention) chiefly because no one has thought fit to design the expensive versions necessary. It is a matter of conviction, rather than conclusive proof, that a gas turbine can be designed and built soon, with an inefficiency not much more than 50 per cent. Moreover a great proportion of the heat rejected by a gas turbine—which accounts for nearly all the inefficiency—can be so rejected at a temperature or in a "grade" which renders it directly useful. A steam generator set, if it is to operate with an inefficiency of say 70 per cent must reject most of its waste heat at an unsaleable temperature, nearly atmospheric, and must suffer greater inefficiency the hotter its rejections. A gas turbine on the other hand rejects at say 250°C (the figure varies widely with the design) and can therefore sell its waste-heat.

The foregoing example will have suggested some cases wherein fuel economy could usefully be studied. The nature of the problem is well understood. Higher working temperatures, higher pressures, more efficient heat exchangers of one sort and another, shorter warming-up times, and—in general—more expensive technique: these give the desiderata for less inefficient use of fuel.

What is the nature of the extravagance of fuel consumption?

Primarily, and in relation to heat engines, it lies in the inevitable use of cycles of operation which impose fundamental limitations on economy thereby making

some inefficiency inevitable. Heat has, however, in practice to be rejected. So that economy must be made by getting as much useful energy as possible out of the fuel. This is primarily an engineering problem. Then we must use as much as possible of the *remaining* available energy, such as exhaust or condenser heat, for some other purpose. In other words, decrease the thermal inefficiency of the engine and reduce the waste inevitably associated with its operation.

All the time, engineers are seeking to do the former, but it has never seemed to be anyone's business to ensure the latter.

In other types of fuel consumption, such as domestic or institutional heating, the types of waste, often amounting to gross extravagances, are: first, allowing heat to be carried away uselessly into the free atmosphere; second, heating a lot of things uselessly in order to ensure heating one thing usefully; and third, permitting heat to be lost by radiation. This aspect of fuel economy has been so fully dealt with in Reports, Press articles, and so forth during the last couple of years that I am sure you need no enlargement. Suffice it to say that the topic is one in which industrial interests compete between themselves to their general detriment, and scientific knowledge or even mere commonsense competes with sheer human prejudice to a degree unheard of since the days when the earth was flat.

There are many varied fields, some of considerable magnitude, in which fuel economy could and should be practised. Many manufacturing processes evolve heat energy derived from the reaction of fuels, incidentally, as it were, but at the same time require wastefully produced grid power to drive the plant involved. Very little has been done towards making such processes self-driving. Examples of these power-operated exothermic processes are blast furnaces, open-hearth and Bessemer steel-making, and the manufacture of nitric acid. Another type of operation is drying. You would be astonished to know how much coal is used to dry things, or drying and cooking them—such things as bricks. I have no collective figure, but I imagine, extrapolating from the few figures I have, that in the United Kingdom at least a million tons of coal per year are used in drying various textile products alone during their processing. As far as I am aware practically no one has thought it worth while to try to save say 50 per cent of his coal bill by using the quite well-known "pressure still" cycle, in which the latent heat of vaporization, put in to effect drying, is recovered instead of being expelled with the water-vapour dried off.

And so the sorry story goes on. I want to be strictly fair about this, and to emphasize to you that each suggestion for economy of fuel, would if effectively performed cost a great deal of capital. As a nation we have always been very shy of making capital investments as a step towards conservation; that is almost traditional. When we had money to burn, we burned it: that is to say we got into the profligate habit of treating it as if it were some priceless, irreplaceable asset such as coal or oil. Now we have so little available capital, like coal, we just cannot afford to use it except for essentials. So, we cannot raise capital to invest in economies. We continue to build cheap, extravagant, power stations, so as to waste 70 per cent of the fuel we toil to bring to them. We continue to

pour 90 per cent of our domestic coal out on to the roof-tops and our neighbour's washing—and are fools enough to do it by sucking cold air through the room to abet the process. We warm a streak of air from London to Newcastle overhead of a train which is quite incidentally hauled in the process, but cannot afford to warm the passengers travelling under it, and to do this we carry coal from Newcastle to London. We use coal to make town-gas and then allow 80 per cent of its heat content to go up chimneys.

What fools we mortals be. If we were to spend in five years what we waste in fuel on economizing it, we would have a coal production surplus (albeit temporarily), some reasonable comfort, cleaner air to breathe, better services and cheaper energy. But we do not invest capital to prevent waste: we do it to increase our losses by wastage.

The *per capita* consumption of fuel the world over is represented by a steadily and too-rapidly rising curve. This applies not only to fuel collectively but to the common individual fuels. This sets enough of a problem, but when the number of heads is also rapidly increasing, the problem is not only difficult but serious. Statistics in this matter are complex, also inaccurate, and misleading in some respects—and in the cases of some fuels impossible to get. It is known for example, that the *per capita* consumption of food-stuffs has increased greatly over the last century, being an aspect of a rising overall standard of living. Consumption of fuel food, however, is virtually the only example of fuel consumption on a revenue basis: and it is not definitely true to say that the world cannot increase its revenue in terms of food. It has been estimated, for example, that the food revenue of about four acres of land (taking good and bad together) is required to feed one human being. If this be related to population, about six thousand million people could be fuelled, all workable land being assumed to be exploited. The present population is probably around two thousand million, increasing twenty million or one per cent a year. Were it not for the fact that the difficulty of creating the revenue is obviously very great, it seems as if the world population could be trebled before starvation automatically prevents further increase.

Practically every other fuel—i.e. the fuels which are used to release energy by non-animal processes—is capital. It may be helpful to list a few of the more important kinds, and to review the position of the deposit account. My figures are taken from various sources, and are highly suspect (at least to me) for accuracy; but they do represent the best I can find, and we should be doing less than our social duty if we ignored the moral they point.

Coal and oil are obviously the two fuels which on a short or medium term view are the most interesting.

Beneath the non-Russian world there are proved reserves of hard coal of about 304 thousand million metric tons, and of brown coal and lignite about 59 thousand million. Of suspected and probable reserves there are some 2,890 thousand million tons of hard coal in North America and the United Kingdom.

In North America the known reserves are 42 thousand million metric tons: the known consumption for 1950 was about 452 million metric tons. The

consumption is increasing, apparently, at a rate of about 4 per cent per annum. In the United Kingdom the known reserves of hard coal are about 130 thousand million metric tons (suspected and probable add about 150 per cent) whilst the inland consumption in 1950 was about 205 million tons with a rate of increase averaging about 3 per cent annually.

I well know how dry and dull such statistics can be. Our interest, I suggest, lies not in the actual figures in tons but in their interrelationship.

Those whose business it is to "prove" oil reserves are far more conservative in their claims. Estimates of proved reserve do *not* include the oil in unproved parts of partly developed fields, in untested prospects or regions known to be worthy of prospecting in certain types of natural gas-yielding areas, or oil which may be made available by synthesis.

With these enormous reservations, however, the ratio of known, proved, reserves of oil in the non-Russian world, to the 1950 production was about 26 to 1.

It is interesting to consider one other set of figures and then I am finished with statistics of this kind. The United Kingdom in 1950 consumed over 200 million tons of coal; and in the same year consumed only 6½ million tons of fuel oil. Thus, our oil consumption replaceable by coal is between 3 and 4 per cent of our coal consumption. In 1948 the ratio of oil produced to coal produced in the United States was 5 to 6. I do not know how much of each was exported or imported.

When you consider the problem from the viewpoint of imports, you should note that, whereas we have to buy and import about 30 per cent of our personal human fuel, we only import about 4½ per cent of all other fuels which are coal substitutes.

I do not know the cost per ton of human fuel. It is known, of course, that oil fuel costs a lot more than coal. Though I have not researched the point, I believe that it costs about three times as much per ton by the time it is burned. Against this, the average energy value of oil per ton is nearly twice as great as that of coal, which readjusts the effective cost difference between oil and coal to about 1·5 to 1 rather than 3 to 1. Moreover oil fuel is usable with much less inefficiency than coal, and although it defies economic analysis to prove the point, I think it is safe to say that, overall, the cost of using fuel oil is far less than that of using coal, and I mean overall National cost.

The picture I have outlined tells us quite a lot about our position, and I should like to recapitulate and marshal some of the information.

In the United Kingdom, consumption of indigenous fuels is steadily increasing. Any sought-for decrease of inefficiency or other "scientific" economy, will not long conceal the increase.

Oil reserves of the world are incalculable: their existence in vast quantity is probable rather than improbable. Coal reserves in the United Kingdom are reasonably reassuring but the problem of getting that coal offers no room for complacency. Oil is relatively little used in the United Kingdom, but is a highly convenient fuel usable with minimum inefficiency. Coal is essential for many purposes; but is, I submit, not essential for the mere liberation of energy.

The case for using oil, rather than coal, in my view is unanswerable. Any talk

of increasing the domestic consumption of coal particularly to save using oil should be viewed with the greatest suspicion. I suggest that it is a prime duty of both science and the citizen to economize indigenous coal by all possible means, and that economy must be both absolute by reducing consumption and functional by reducing inefficiency.

As to other fuels, it is clear that no substantial economies can be effected in relation to food, so that—food being a revenue item—it is our duty to increase its production. Non-human fuels other than coal or oil should be investigated with a view to their further use as substitutes for coal. And, of course, the same remark applies to any source of energy other than fuel, such as the revenue energy of the sun, in terms of water, wind, tidal, photochemical energy, or direct thermodynamic use of solar heat.

I should like to refer to one or two other kinds of fuel, merely to complete the record. Let us remember that nature has a half-way house between vegetation and coal, namely peat. In Ireland about 7 million tons of peat are burned annually. (It is interesting to note that 7 million tons of human fuel in the form of grain are said to be consumed annually by rodent pests in the United States.) There are vast deposits, in Europe, North America, Northern Asia. It is an unhandy fuel, because to handle a ton of usable peat you have to handle at some stage about two tons of useless water. And even when dry enough for ordinary use, peat has a low energy content—only about half that of hard coal per ton. Nevertheless peat is a fuel to be reckoned with: and it is a very good thing that even its high water-content can be turned to good account in one use now under investigation by the Ministry of Fuel and Power, namely by burning it in a gas turbine.

Natural gas is enormously used. It has much of the convenience of oil, in that it can be piped. It is also amenable to processing to yield oil, and for other purposes. Methane, liberated by seeping out of coal, and rotting vegetation, is a useful fuel. A picturesque contribution in this context also comes from the Ministry of Fuel and Power thus: the upcast ventilation air from a coal-mine contains methane, albeit very dilute, say 1·5 per cent or less. It has been realized that this very "weak" mixture will burn if pre-heated. Investigations now afoot, again using a gas turbine, may result in generating electricity from this neglected fountain of energy. Such generation at the pithead has the great advantage, of course, of saving transport.

There are indications of a cautious, almost stealthy, kind that the chemist is thinking about the concentration of energy in various other fuels, not so much to increase the available fuel resources but, perhaps, to render them less inefficient in use, transport, and handling. We suffered from one such effort, in connection with the V2 rocket. The fuels which propelled this were hydrogen peroxide, ethyl alcohol and liquid oxygen in three-sided reaction, a combination with a very high energy content. Somewhere about three times as high as a kerosene-air combination.

Oxygen deserves special study. As you all know, it is provided by nature as about 20 per cent of the atmosphere by weight. To use it in its free state as a fuel,

you therefore have to involve in your combustion process about four parts of inert gases to every part of the essential oxygen. If the process is one in which the gaseous reagent has to be blown (as in a blast furnace) or compressed (as in a gas turbine or a petrol engine), you have to spend some of the other reagent (coke or petrol) for such blowing or compression. Moreover, whilst it is useful in some cases to have the inert 4/5ths of the total air present as a diluent or as a conveyor of heat, in many cases it is not. There is in a large number of instances a strong case for using oxygen in a relatively pure state, getting near to 100 per cent rather than 20 per cent of the gases involved. Some fuel reagents will not burn at all unless reacting with concentrated oxygen. We must keep under review, then, the possibilities inherent in using so-called "tonnage" oxygen in our survey of the use of fuels. It will consume energy to concentrate the oxygen, but we know that relatively low-grade energy can be used for this purpose, and we throw away so much low-grade energy, anyway, that its use cannot but be a functional economy, and examinations now current strongly indicate that there may be substantial energy-profit to be derived from a complete transaction. The typical case might be a blast furnace. Such a cycle would almost certainly best be achieved by the use of gas turbine technology.

A great deal could be said about the possibilities of creating other fuels from common materials. These must necessarily depend on endothermic processes so that in turn heat may be released by exothermic processes at the later stage of use. It may well be that the endothermic reaction will be found to be convenient when promoted by otherwise difficult or unwieldy heat sources. For example, whilst it may be difficult to manage a release of nuclear energy so that it can conveniently be used to generate power, it seems to me to be no great stretch of imagination to suggest that nuclear energy might be used to procure carbon from highly plentiful chalk, so that the carbon could in turn be recombined as a fuel with oxygen, all three elements, calcium, carbon and oxygen then being available for use as fuels or otherwise.

I would dare to prophesy that, within a life-time, chemical ingenuity may produce fuels of a very highly concentrated but still non-explosive type, from cheap material. The process which, though it must I suppose be in itself endothermic, may use low-grade heat, solar energy, or other revenue energy, in its synthesis. I recall very well that this line of thought was suggested enthusiastically by Sir Frank Whittle in 1942 or so, but could not then be followed. If my prophecy comes true and is cheap to perform, the economic situation of the world could change overnight.

Having ranged somewhat at random over the nature, distribution, and application of fuel, I now wish to speak of its abuse, and to touch on ways in which that abuse is being or may be countered.

The main abuse of fuel is the inefficient use to which we put it.

The second abuse is the use of a wrong fuel for a given purpose and a third the use of fuel where none should be used. A very great deal remains to be done to remedy the main abuse and it is only fair to say that conscientious engineers and scientists are constantly applying themselves to the problem. Thus the

inefficiency of various types of prime mover—and I would here refer particularly to the various types of diesel engine—has been very greatly reduced during the currency of such machines. It is disappointing to notice that the oldest type of prime mover, the steam engine, although undergoing enormous favourable changes during the first half-century of its existence, has not had as much attention paid to it during the last half-century. Indeed the overall thermal inefficiency of plant type steam engines has not been reduced, except marginally, for several decades, nor has any very serious or large-scale attempt been made to turn to good use the fantastic proportion of heat which such engines reject. This is probably because such engines are mostly designed and built in countries where fuel has always been reasonably plentiful. If coal had always cost £15 a ton in the United Kingdom I do not suppose that this would have prevented the introduction of steam engines, but I am sure it would have resulted in at least twice as much useful energy being derived from a ton of coal through the medium of a steam engine as is being derived to-day. No doubt the capital cost of a steam engine might have been twice as great as it is, but one cannot countenance that as having any serious bearing on the matter or as an excuse for inefficiency of so great an order.

The internal combustion engine has developed on the other hand in two distinct ways because its applicability covers such great range. The greatest numerical proportion of internal combustion engines consists of the small sizes, the relatively short life light weight type of engine typified by the motor-car engine. At the other end of the scale, the requirements for convenient and economic power for ship propulsion called for slow, heavy, long-life and very efficient engines. The result has been great refinement in both directions so that we see—or could see ten years ago—internal combustion aero-engines of relatively poor efficiency, but with terrific power output, and to-day we have marine engines of great size and weight running at slow speed with relatively little inefficiency. The newcomer in the field is of course the gas turbine. It is interesting to note that the gas turbine, being essentially a war baby, was first developed mainly on the lines of extremely high output and relatively great inefficiency. Enormous strides are now feasible in the other direction: namely, to adapt the gas turbine to industrial purposes, and in so doing to try to combine some of its original attributes of lightness, compactness, and simplicity with the necessary economic attribute of low inefficiency. The industrial gas turbine is undoubtedly on its way in, and whilst I do not foresee that it will displace either the diesel or the steam engine for all purposes, yet I have no doubt that within the active lives of many of us it will not only replace some diesels and steam engines but will also increase the total number of prime movers put to the service of mankind. The gas turbine is unique in that its range of application extends from the very large plant type of machine to the small portable class without marked variation of the design approach. Moreover, its essential ingredients, subject only to adaptation and rearrangement, can be used as power plant energized by the combustion of fuel, or as power plant energized by the transference into itself of heat from some existing source. The gas turbine is the

most catholic of engines in terms of the type of fuel upon which it will run. It can well run on waste heat—e.g. from a furnace—and can be adapted to operate from a source of heat at what is normally regarded as too low a temperature to be otherwise used. A particular species of gas turbine known as the "inverted cycle" can be shown to be economically operable from a source of heat as low as, say 350° Centigrade, or even lower providing that there is an adequate sink for heat in the nature of a river or a cooling pond.

Having been much concerned with the development of gas turbines myself, I find it difficult to curb my enthusiasm for their prospects and their engineering beauty. The records of inventions are bespattered with other types of engine intended to convert the energy of a fuel into a useful mechanical form. Some of the devices suggested are fascinating in their ingenuity: some definitely show theoretical promise of success and a few have actually been made and been demonstrated to be effective. There is none known to me outside the range of which I have spoken, which seem to combine the necessary requirements for industrial use. I think we may take it as a fact therefore for working purposes that unless science and the inventor produce something so new as to be unforeseeable to-day, perhaps on electrothermal lines, it is the existing means and machines that we must develop and modify and refine in order to avoid abusing the fuel at our disposal. Such development will no doubt involve not only technical improvement in the engines themselves by way of reducing their inefficiencies, but also the redeployment of various species of engines in such a way that arranging them in series or cascades, we can use liberated heat energy from fuel in grades so that various temperature ranges can be economically applied to the particular range of work which they suit best. For example, a power station with a steam engine may well be so designed as to use the higher temperature range of its furnace heat output directly for electrical generation, the next temperature range for district heating, and the tail end of its temperature range for energizing a heat pump for whatever service may be required of it. It has been calculated that an overall thermal efficiency expressed in terms of the calorific value of fuel burned in proportion to the total amount of saleable energy may be as high as 80 per cent. That means that there is a possibility of an inefficiency of only 20 per cent and, although the initial capital cost might be enormous, I still maintain that the capital cost factor is practically insignificant when it is weighed against the urgency of the fuel resources problem.

So much then for fuels in connection with mechanical or industrial energy. Domestic heating is an entirely different problem but not one on which I can throw any more light. I can do no more than echo the hypotheses and suggestions of bodies like the Coal Utilisation Council, Smoke Abatement Society, and many others whose admirable mission in life is to teach people how to use domestic fuels properly. As for industrial processes and processes divorced from the production of mechanical or electrical power, I can only say that over the last five years my technical colleagues have examined many examples ranging from simple drying of commodities to elaborate chemical processes such as that of the blast furnace or the gas works, to conclude that a very large proportion of them

(and nearly always the cases wherein huge absolute tonnages of fuel are concerned) can be shown to be amenable to improvements up to 50 per cent of fuel saving, by modern technology and the spending of much capital.

The fact is that we must spend to save, there is no way out of it. To use fuel is all too easy: to avoid abusing it is both imperative and costly.

DISCUSSION

THE CHAIRMAN: The lecturer has put his finger on one very important point, namely, that capital expenditure precedes high efficiency. It is, of course, our duty to find out where we can effect the greatest saving with the smallest capital expenditure. The lecturer alluded a few times to the question of the utilization of waste heat, and it is clear that the amount of this heat is going to increase very considerably. In order to compete in world markets, we must vastly increase the consumption of electricity in industry and by the end of the century the waste heat from this increased electricity production may well be of the order of the heat produced by burning 50 million tons of coal. We certainly will not be able to afford to let all this energy go to waste.

On the other hand, it is not very easy to make use of great amounts of low-temperature heat, and this brings us to an important point. It is quite certain that district heating schemes fed from back-pressure turbines will necessitate higher capital expenditure than do the conventional ways of heating, and the question is how to encourage such schemes. I believe it is absolutely necessary for new settlements to be designed to use this waste heat and this means that some planning will be needed. If I understand the recommendations of the Ridley Committee properly, they are against such planning. More or less, their report boils down to saying, let everybody do what they like. I cannot see how this can lead to satisfactory results in all those cases where the barrier of high capital investments has to be overcome. The mess in which we find ourselves at present in the field of fuel and power has certainly been arrived at without planning.

The fact that capital expenditure is needed to attain efficiency applies, of course, to all aspects of our national economy, and it is a great danger for this country that we do not make the necessary capital available. I am thinking particularly of technological education, which is very intimately connected with what we have been talking about, because in order to save fuel we need an improved technology and a great number of highly skilled technologists. The present system is not providing this.

I believe that most people would now agree that we need something like an Institute of Technology; but what is the official reaction? One hears, "Oh, it's too expensive, one of them would cost something like five million pounds". I think that is a very small sum, compared with what is at stake. It is really very depressing to see this attitude, particularly if we consider that to judge from what other countries do we need something like ten institutes of this type.

One other point: the lecturer emphasized that it would be very desirable to increase imports of oil in order to reduce the demand for coal, and he gave some indication that this might help our food supplies. I should like to hear a little more about this. If there is time, I would also like to hear a little more about the "inverted cycle" to which he referred, which has these relatively high efficiencies at low temperatures.

THE LECTURER: In regard to technical education, I am completely in agreement with the chairman. I do not think that in this country the present vicious state of affairs can or will be remedied until management acquires some technology. There is not enough technical management. I am not a proponent of a complete technocracy, but I am a proponent of the notion that the management of a technical business

should know something of what it is managing, and that is something lamentably absent to-day.

In regard to oil *versus* coal, whether we should import oil to economize in coal; there are really two aspects. I admit to having a bee in my bonnet about this. I have come to believe, from the whole examination that I have been able to conduct, that it is a fallacy to say we should increase the consumption of coal in order to save importing oil. I base that largely on the relationship between the importation of oil and that of human fuel, and the point I have been asked to enlarge on is this: I am, of course, not an agronomist, but I suspect that if we were to increase the importation of oil fuel into this country by, say, a half per cent of the whole of the fuel used, and devote that increase to the further production of food, we might well decrease the importation of food as much as half. I do not know; that is very largely a subjective remark, but that is my feeling at any rate.

In regard to the inverted cycle, I am afraid, short of showing a drawing, it is not very easy to explain, but to those of the audience who think in terms of gas turbine language, we call an inverted cycle a cycle in which the working fluid is a hot gas—shall we say a flue gas or something of that kind—coming from a chimney which runs direct through a turbine, from which it goes to a cooler, there being no combustion system present, and from the cooler it is pumped back to atmospheric pressure by a compressor driven by the turbine. It is the exact mirror image of the open cycle turbine. That is what we call the inverted cycle. I think those were the main points the chairman mentioned.

THE CHAIRMAN: Have those machines been produced?

THE LECTURER: Not to my knowledge.

THE CHAIRMAN: May I underline one point? We really need more technologists for management. A short time ago a colleague of mine from America visited me and was very much amused to read the company reports in our newspapers. He said, "Although the reports were all very long, I could not find out what the company was making, whether it was liver pills or motor cars. No mention of this at all, only financial and administrative aspects". I think that is quite true. Most companies are run by financiers and accountants only, a very severe handicap for our industry.

MR. A. PARKER, C.B.E., D.SC. (Director, Fuel Research Station): I came only to listen on this occasion, particularly as I did not know in advance how Mr. Johnson would deal with his subject. He has covered such an enormous amount of ground that to discuss all the factors fully would occupy more time than the lecture. Mr. Johnson has given us a most interesting and broad survey. Naturally the estimates of reserves of different kinds of fuel, what I call fossil fuels, must be approximate, but I do not think that the estimates that are available are quite so unreliable as perhaps Mr. Johnson might have led us to believe. Obviously, when estimating reserves of coals and lignites, there must be limiting conditions. Usually for coals, only those seams are considered that are not less than one foot in thickness and not more than 4,000 feet below the surface. Those are reasonable limitations on the basis of economic possibilities. At the present rate of world consumption of coals and lignites, the total known and highly probable reserves would last for about 5,000 years. But the whole of those reserves could not be economically brought to the surface, because of underground waters, faults in the strata, and other difficulties. It would be unwise to rely on more than one third to one half. Even so, the quantity is two thousand times the present annual consumption.

But the important point is, that on the same basis of calculation, the coal reserves of this country would last only two hundred or two hundred and fifty years, as against an average for the world, on the same sort of calculation, of two thousand

years. It must be remembered also that the most advanced of industrial nations, or the most politically powerful, say, the United States of America and Russia, are on the two thousand years' basis, whilst we are on the two hundred to two hundred and fifty years' basis.

Then there are other countries like China, believed to have very large reserves of coal, but not yet developed industrially; they will develop in time and be in competition with us in industry. We shall certainly have increasing industrial competition, and in meeting it we shall have to rely for a long time mainly on coal as our source of energy.

The known reserves of oil would last, at the present rate of consumption, for only twenty to twenty-five years. No doubt more oil resources will be discovered, but I would not like to assume, against the two thousand years for coal, that we are going to have liquid natural oil economically produced for longer than, say, one hundred years, which is a vastly different sort of figure.

I should also mention oil shale. The reserves of oil in oil shale—the known reserves—are much greater than the known reserves of natural petroleum. But even including shale oil, the amount of oil in reserve is very small in comparison with the amount of coal. There is plenty of peat in the world, but the reserves are also very small compared with coal. We certainly cannot afford to waste fuel in this country.

I think quite a lot can be done, at the moment, without spending an enormous amount of capital. As a conservative estimate, I believe that we could cut down our fuel consumption in this country, merely by decreasing inefficiency, by roughly 10 per cent. We are using about 200 million tons of coal, 20 million tons of oil, and some wood, bringing the total coal equivalent to about 230 million tons. We could probably cut that down, with our existing knowledge, and without great capital expenditure, to 200 or 210 million tons; but it does mean education. The methods are known, but we must train people to use the more efficient methods. Beyond that it will mean heavy capital expenditure and new methods; but the cost of the fuel used in making the equipment, in transport, and so on, must also be taken into account. In the end, if the costing is right and there are no subsidies, nor one part of the process subsidizing another in some hidden way, I suppose the best of all bases is the cost of the service to the consumer.

The total amount of oil we use in this country—I do not know whether I misunderstood Mr. Johnson—is more than the figure I understood him to give. Our net import is about 20 million tons of oil. I know that only 5, 6, or perhaps 7 million tons are used as so-called fuel oil, but we use quite a lot of lighter oils for internal combustion engines.

When we consider only efficiency or inefficiency, we are liable to forget the psychological factor. I am not going into the complications of thermal-electric district heating schemes at the moment. But let us take the simple district heating scheme with a central boiler supplying a whole group of houses. It is assumed that there is higher efficiency with the central boiler. In fact, that central boiler, burning coal, is of only about the same efficiency, or inefficiency, as a good domestic boiler burning coke in the individual house. Since at the moment the overall cost for the district heating scheme is met by putting the average cost on the rent of each house, human nature being what it is, there is little incentive for the householder to economize in heating and in the use of hot water. Surveys show that in district heating schemes for small houses, the amount of coal consumed at the central boiler, purely for space heating and hot water, not including lighting, cooking, radios, and vacuum cleaners, ranges from 5 to nearly 7 tons a year. Yet the average fuel consumption for houses of that size in this country, taking everything into account, lighting, heating, cooking, vacuum cleaner, radio and all the rest of it, is in the region of 4½ tons.

That is because the charge is in the rent. Admittedly the householders have greater comfort and less work, but more fuel and water are used. The whole problem is not

just fuel efficiency from the scientific and technical angles; there is also psychology, and in relation to oil there are international questions. I do not want to discourage people from saving fuel, I want to encourage them, but these other factors must not be forgotten.

THE CHAIRMAN: Certainly the psychology has to be considered and human nature has to be controlled. You have to introduce heat meters so that people do not simply waste heat.

THE LECTURER: I think Professor Simon could, of course, answer all the last speaker's points very much better than I can.

I am obliged to him for pointing out the apparent discrepancy in oil importation. In the first place let me defend myself by saying it has been extraordinarily difficult to get any accuracy of figures. I do not think there is, in fact, a very wide discrepancy between the figures we have given, on a true interpretation, if $4\frac{1}{2}$ per cent of the thermal energy used is the accepted basis. My yardstick is, oil imported for consumption where coal could be used. Then his figure, which is something like nine per cent, is approximately the same figure, I think; 20 million tons total import, not consumption. It must be remembered, of course, that, taking total consumption, including all that oil processed for uses irreplaceable by coal or converted into lubricating oil, the proportion stated is relatively small.

As to his point on the economics of district heating; it is a perfectly valid statement that district heating is not in itself, as a heating system, any better or any worse than any other. That is not the point at issue. I would, of course, encourage —and I think everybody in the room would probably encourage—district heating, providing it can be supplied entirely by waste heat. That is really the point I seek to make.

As to the question of economizing in some degree by education, and thereafter by capital investment; again I am in entire agreement with the speaker. The only thing is, I should put the potential economy through education at a very much higher percentage than he would be prepared to.

PROFESSOR J. F. ALLEN, F.R.S. (University of St. Andrews): I wonder if I might say a word about district heating and its economy? I come from a place in Western Canada, where district heating has been used for over half a century; that is the city of Winnipeg, where the whole city—about 300,000 people—is heated from two or three plants. They get over this question of human nature, of course, by charging for the amount of heat used. The heat is metered for the house, and there is no question about it, if you do not use the heat, you do not pay for it. I have always believed it is nonsense to put this sort of thing on the rent or on the rates. I do not see why the heat should not be metered as well as anything else.

Incidentally, it has always struck me as being very amusing that in this country one does not have water on the meter. One can use as much water as one wants and I think this is quite stupid in a country that has a limited amount of worldly wealth. Why should we just throw water down the drain because it comes on the rates? We should pay more attention to these things in this country, and pay for what we get. Heat and water can be metered just as cheaply and economically as can gas and electricity.

MR. G. J. GOLLIN, M.A., M.I.MECH.E.: In a programme on the television in the last fortnight the statement was made that, unfortunately, it was impossible to charge people by meter for the heat they consume. It is rather extraordinary that in so many other countries the impossible is achieved. Perhaps they meant it is very expensive to make the meters; but it is by no means impossible.

The other point that should be brought up is that the custom in this country, up to now—up to the twentieth century—was not to heat houses, but to provide what is

known as background heating; that is, you give a little local heat in part of the house for part of the time. If we come up to date and heat a house as the Egerton Report says it should be heated, everybody says, "Oh, it's beautifully comfortable, but so expensive", comparing it mentally with the form of background heating which is only partial heating.

THE CHAIRMAN: May I add a few words about the heat meters? I believe an exact heat meter is really very expensive, but there are quite a number on the market which measure within five per cent or ten per cent, which is quite sufficient to divide the relative costs of the whole heating between various people.

MR. A. PARKER: I am sorry to interrupt, but I think the speaker was referring to what I said in a television broadcast. May I correct it by saying that I did not say it was impossible to measure the heat, I said it was not, at the moment, entirely practicable. I am hoping it will be when more investigations have been made.

MR. COLIN TROUP, B.SC., A.C.G.I., A.M.I.MECH.E., A.M.INST.F.: It is very difficult to be impartial when discussing matters of fuel policy, and I think the lecturer's enthusiasm for liquid fuels and gas turbines has rather led him astray. On the liquid fuel side, particularly in relation to the relative efficiency of oil and coal for industrial use on steam boilers, I think his figures are rather optimistic, but I will leave that point to someone else to deal with.

The point I want to raise is in connection with the lecturer's remarks on the efficiency of the steam engine which, he said, has hardly improved over several decades. I think he has in mind the old type of slow-speed jet-condensing engine used in large numbers in the mills of Lancashire and Yorkshire in the early part of the century. Since the introduction of the high-speed engine with a surface condenser, the efficiencies have been considerably improved, although to-day there are very few condensing engines going into industrial plants in this country; obviously because one cannot generate electricity in a small condensing plant as cheaply as one can by buying the electricity from the public supply.

There is another type of steam engine which the author did not mention, namely the back pressure set, in which the steam is used for power generation first, and then for process heating, which gives an overall thermal efficiency of between sixty and seventy per cent or, to use the lecturer's nomenclature, an inefficiency of only thirty to forty per cent. These engines are being used increasingly to-day, and it is thus somewhat inaccurate to say that no large-scale attempt has been made to turn to good use the fantastic proportion of heat which steam engines reject. By using back pressure sets one can, as I have said, get an overall efficiency of 60 to 70 per cent.

I made a quick check this morning with one of the principal firms of steam engine manufacturers, and they told me that during 1951 and 1952, the total value of the engines they sold came to the sum of three quarters of a million pounds, which is quite an appreciable figure. Of those sets, in 1951 76 per cent were back pressure engines, and in 1952, 83 per cent were back pressure sets, so I do suggest that quite a lot is being done to improve the efficiency of the steam engine; and rather than condemn it, if the use of back pressure sets for industrial purposes was further encouraged, we would go a long way forward on the road to fuel efficiency.

THE CHAIRMAN: Have they sold these machines in this country?

MR. COLIN TROUP: Yes, I should have said that the figures I quoted were purely for industrial machines supplied for use in this country.

THE LECTURER: I am in entire agreement with the last speaker. When I said on a large scale, let me put that against the background of the lecture. What I was seeking to imply there, was on, as it were, the power station scale. I did refer to the fact that,

by the systematic application of engines—which would certainly, in my view, involve the back pressure steam turbine at some stage—an efficiency up to the order of 80 per cent is achievable. I entirely endorse that; there is no conflict of view. It is, however, still the case, I think, that the intrinsic efficiency of a given steam engine as a prime mover has not substantially increased over several decades. On that point I disagree with the last speaker. What he has made out a case for, as I understand it, is so building a steam engine as to render its waste heat saleable. But he will, I think, agree that that is at the expense of the inherent efficiency of the machine as a prime mover.

MR. J. F. FIELD: I have listened with great interest to Mr. Johnson's lecture. One of his suggestions was for a waste heat gas turbine which would in effect work from a pressure of one atmosphere down to a pressure of about one fourth of an atmosphere. The idea is theoretically sound, but I think there is no doubt that it would require at least a similar heat drop to that of an ordinary gas turbine, and it is a matter of experience that most gas turbines will not supply enough power to maintain their own rotation at full speed with an upper temperature of less than about 500°C. Furthermore, the bulk of the machine would be relatively large and the kilowatts available relatively low in relation to the waste heat supplied, unless the available temperature were considerably higher. The cost per kilowatt would also be relatively high at low efficiency, and this effect would be quite inadequately compensated for by the avoidance of so-called critical materials.

The British Electricity Authority is obliged to throw away heat on a very large scale in the production of electricity. At the moment the temperature at which this heat is thrown away is considerably too low for house-heating, but the quantity of heat involved is colossal and is increasing rapidly with every year that passes. When electricity production is doubled, and possibly redoubled, within a comparatively few years in the United States, we as a nation will have to follow suit because world economics will force us to do so. This vast increase in electric power will be required for industry, and especially for the new metallurgy of the light metal age which is looming on the horizon, and for the other chemical and refining processes of modern industry: for example the preparation of fissionable materials. The inevitable result by present methods of electricity production will be a huge increase in the demand for coal and in the production of waste heat rejected to condensers, cooling towers, rivers, and the like. It is inevitable that increasing pressure of public opinion will be brought to bear on the question of using this waste heat as a substitute for coal, so that the latter can be released for greater electricity production and so improve the collective coal efficiency of our heat and power requirements on this island.

If one looks far enough into the future, the waste heat could be a drug on the market and the question of its basic cost will be completely subordinate to the capital cost of distributing it to the user. I recently made a rough estimate of what it would cost to connect up say ten million homes out of the thirteen million or so in this country for district heating, and the figure came out very roughly between £2,500 million and £3,000 million—but it could be the means of saving at least fifty million tons of coal per annum. If anyone finds himself boggling at this huge figure, he should remember that the nation is spending in peace-time at the rate of some £5,000 million in three years on tanks, guns and aeroplanes; whereas this proposal would necessitate the spending of a maximum of say £3,000 million in twenty to thirty years. The rearmament burden is a somewhat painful one, although not by any means unbearable in all the circumstances, and a substantially smaller burden over a much greater period of time has the advantage that it would be very good business for the health and wealth of the nation to do it. It should be possible by this means to free somewhere between fifty and a hundred million tons of coal at present used in domestic grates and in Lancashire boilers. That coal can make electricity first, and with certain

new kinds of generating plant now being thought about, can make at least twice as much electricity as with conventional plant, before the waste heat is piped to replace the domestic hearth or the Lancashire boiler in the factory.

There can be no question that a vast increase in the production of electricity is vital to national prosperity, and even survival, in this highly industrialized country. Vast sums of money will also be required to replace almost completely the present electric generating plant of this country over the next thirty or forty years, so that the combined capital expenditure on the fuel and power industries as a whole will be astronomical. They will compare with the sums spent on national defence, and they are at least as important because a collectively efficient fuel and power industry is the very mainspring of the industrial survival upon which our defence effort must rest. In fact in the end you cannot have in Britain any worthwhile arms industry (regrettable although the necessity for that is), or any welfare state or any of the other things that western civilization considers worthwhile, without a supremely healthy fuel and power industry. I believe we shall be thinking before many years have passed in terms of a budget of between £500 million and £1,000 million a year on the fuel and power industries taken collectively, and there can be no question at all that the money will come back to us multiplied many times in other forms of national wealth.

For good or ill, we are entering a new phase in the Industrial Revolution, based on the use of mechanical power. It is being stepped up to a completely new plane of intensity, mainly on the initiative of America, and we have no choice but to follow suit. We can also imagine the tremendous efflorescence of new ideas in this country implicit in the coming of uranium fission, but the raw material for this art must mainly come from abroad, and a future Dr. Mossadeq will not sell us the uranium for next to nothing. Whichever way one looks there will be a need for this country to strive for the last ounce of exploitation of scientific knowledge to harness to our industrial production effort. At the moment we are exploiting nothing like the full amount of our knowledge of science as applicable to the fuel industries; but apart from a drastic change of ideas, we do need vast amounts of capital, and it should be approached in the same spirit as the expenditure on national defence, with the difference that a large proportion of the expenditure will be for the benefit of mankind—and not for his destruction.

The question of metering centrally produced heat to buildings has been raised by another speaker because of the need for economy in the use of such heat. A great deal depends on where the heat comes from. If it is produced in a boiler as a primary product, the need for economy is obvious. If it is a by-product of the production of electricity, as it should be, the question of metering has a somewhat different aspect. In Britain there will be a vast amount of waste heat and the true cost of waste heat from the production of electricity will be small in relation to the capital cost of distribution, so that the means of utilization would commit the country to nine tenths of the cost of waste-heat heating domestic premises whether they used it regularly or not. Hence there is a good deal of virtue in the old-fashioned British negligence in refusing to meter domestic water and waste heat, but in levying a fixed charge for an all-in service based on the rateable value of the premises or some rough-and-ready criterion of that kind.

THE LECTURER: It seems to me that nine-tenths of the last speaker's remarks are entirely non-controversial. I utterly agree with him and am much obliged to him for putting things in a clearer way.

I should like to make one comment in regard to the inverted cycle. The question of size has been taken into account; this is to a certain extent offset by the fact that in the low temperatures with the inverted cycle you are not using critical materials, and so, in fact, the first cost element may not be as important as it seems.

Apart from that perhaps I may be forgiven for not going into it in great detail, but that could be dealt with privately, as it were, on the thermodynamic side.

MR. A. C. HAZEL: As a technical manager I feel at a disadvantage with so many scientists present, and I was getting very worried indeed when the gentleman ahead of me talked about £3,000 million to supply district heating to domestic dwellings. I gathered there are over twelve million of these, so this makes £250 a house. I am beginning to wonder where on earth we are going.

I should like to point out to all scientists present that one of the functions of technical managers is to make profits. I am quite willing to spend £25,000 on improving the heating of my factory, and I am told it would be a good idea, but if I find I am only going to save myself £1,000 a year, I personally, being only a technical manager, am going to have the greatest possible difficulty in convincing my Board that it is an economic proposition. Of course, all this discussion regarding the better use of fuel is a question of economics, and I for one am grateful to Dr. Parker for indicating that we should keep our feet on the ground.

Let us take this case of district heating which we have heard so much about, and the possibility of using heat meters. I personally would be only too happy to sell heat meters to anybody in this room. They do exist; they are in use in this country; there is nothing new about them. If people want them, we want the orders. It is just as simple as that.

Costs, however, and this is the whole point, are quite a different matter. If you go to a local authority and try and sell them heat meters, and say "Yes, you can have these and they cost 27*s.* 6*d.* per radiator", they start thinking about getting their money back, and it is entirely a question of economics. All these technical things can be done, but are they a practical proposition?

I sat and listened to a debate on district heating years ago and we were told it could be done for 4*s.* 6*d.* a house. I have just read the report on Salisbury; the original figure was, I believe, about 4*s.* 6*d.* a house, and I now find it has worked out at 14*s.* 8*d.* a house. I appreciate the lecturer's point, of course, and realize he was really talking about utilizing waste heat for district heating but there are still these difficulties of peak demand and system losses.

Finally, in addition to being a technical manager, I am also a customer, and, therefore, a householder, and I am worried about the scientists telling me what I have got to do and what to use. I have a right to decide the type of fuel I wish to use, so long as I do not annoy my neighbour, and here I take Mr. Johnson's point—obviously I must not annoy my neighbour. I feel the big point he made was on the pollution of the atmosphere but, I would remind him, no less a body than the National Coal Board have deemed it desirable to urge us to burn slack coal on modern grates, which I, as a manufacturer, have produced for smokeless solid fuel, and which I would point out, are only efficient on smokeless solid fuel. If you are going to burn slack on them, you are going back to the low efficiencies of the old-fashioned fire they replaced, and furthermore you are inevitably going to pollute the atmosphere and annoy your neighbours. Therefore, in addition to this being an economic problem, the question is also political, and I would urge all scientists in this room to-day to remember it is a question of economics plus politics, as well as scientific knowledge.

THE CHAIRMAN: I believe the speaker is mistaken in assuming that there are so many scientists in the room. I think there are actually only two or three. Moreover, the gentleman who spoke before him and to whom he referred was an engineer in a highly administrative position.

I happened to read, a few days ago, the works of Count Rumford whose 200th birthday will be celebrated very soon, and I would be very happy if the people who build houses in this country knew half as much as he did 150 years ago.

DR. T. A. MARGERISON: A feature of industry in this country is that it is never prepared to look very far ahead. In 1945, I think it was, it proved impossible to raise the capital required to build the steel company in Wales, and other means had to be used to get this capital. The reason was quite simple: no returns were going to come for five years from that money.

It seems to me that the last speaker suffers from very much the same sort of trouble, he says that his money must pay for itself. It appears to me the only way in which we can improve the efficient use of fuel is to adjust the price of coal until the installation of economy devices does pay. At the present moment I know perfectly well that if I were to insulate my house with Vermiculite in the ceiling I could cut down my fuel bills by a certain amount, but that would cost me twenty pounds capital, and I do not use so very much coal in a year. Likewise, the manufacturer: only a small proportion of his costs in making socks, or whatever they may be, is spent on coal, and education alone is going to do no good at all. The manufacturer will not put in a back pressure turbine set and spend a large sum of money on it simply because he is told by some gentleman in the Ministry of Fuel and Power that a back pressure set would be very good and save fuel. He must get a definite financial gain from it, and he can only attain that financial gain if we adjust the price of coal accordingly.

One other point I should like to make is the need for very much greater research work in certain important development fields. In particular, the amount of work that is going on in this country on the utilization of the gas turbine for industrial processes seems to me to be out of all proportion to the amount of value that could and should come from it. Likewise, I am very distressed to find the very small amount of work being done in this country on the development of fuel cells, which offer an opportunity to produce electricity at a very much higher efficiency than we can do at the present moment.

Finally, there is just one point I would like to make with regard to the importing of fuels. We have heard that our own fuel resources are likely to run out before those of certain other countries, such as the United States and Russia. Surely it is good policy to make use of someone else's capital resources and import as much and export as little as we can. Let them use their own coal but let us reserve our own for times when we may find it more difficult and expensive to import.

THE CHAIRMAN: May I add a word about the fuel cell? It is quite correct that the fuel cell is, in principle, a means of converting chemical energy directly into free energy. An increasing amount of interest is being taken in it, and the British Electricity Authority is now doing quite a lot of work in this field; possibly they could do a little more, but we cannot say it is neglected altogether. If this work becomes promising, I am quite sure more money will be spent on it.

MR. L. LANDON GOODMAN, B.SC. (ENG.), A.M.I.MECH.E., A.M.I.E.E.: With all due respect to the last speaker, I am very much against artificial tampering with the prices of the basic commodities in our economy. I think there has been a little too much tampering with these basic factors recently.

To-day, as I see it, one of the main solutions to the correct use of fuel lies in education. The universities do not help much in providing the type of training that would be useful in industrial production. The work is left very nearly entirely to the technical schools. For example, mathematics are taken in the final year honours courses at universities, which are never used in industry outside possibly the research and design departments. I would like to see the older universities in particular setting an example and conferring higher degrees in production subjects, such as Materials Handling.

We have heard this afternoon an admirable review purely from the fuel outlook. I should like to stress the need for an overall approach. As an example, industrial heating is not a problem for the fuel technologist alone, it is a problem also for the

industrial engineer. High frequency induction heating is a good illustration. The treatment of metals by high frequency takes place with a valve oscillator working at an efficiency of about fifty per cent, but, properly employed, the overall efficiency is much better than that of other types of processes because various factors besides the thermal efficiency must be considered. Firstly, the design of a product may be of a type which would not be realizable by other methods. Secondly, the factory or floor layout can be improved. Thirdly, unskilled labour can be employed. Fourthly, the whole production line can be laid out on the flow principle. Other factors are involved but the above show that the problem is not one of heating alone. It is one of materials processing and materials handling.

An answer to most of the points raised, I think, is given by the title of another paper that is coming later on in this session, which is simply termed "Improving Coal Production".

THE CHAIRMAN: I quite agree with the last speaker about the question of education, but I do not think the universities are the right places, it should be a technological university.

Now, his general remark about not tampering with basic factors. I do not know whether he would call traffic lights tampering with basic commodities or not.

MR. L. LANDON GOODMAN: If traffic lights are fully on at night, when there is only one car, say, every half an hour, then I should say it was tampering. They should be put at a blinking amber, as is done on the Continent.

THE LECTURER: If I might just make two comments on the last speaker's remarks. I do not appreciate his view in saying that there is already too much tampering with basic commodities. Let us be a little more basic and say that every time you dig a shovelful of coal out of the ground you are interfering with a basic commodity! If you are going to use that sort of argument you have got to use it back to its origins. That is just a rhetorical answer, it does not take us anywhere.

Secondly, as to his question of using electrical energy in a certain way, may I go back to my own three cases of the main abuses of fuel? I put as the first the inefficient use to which we put it; the second is the use of a wrong fuel for a given purpose, and third the use of fuel where none should be used. Now, the case that has been mentioned seems to me to be between the second and the third. That is to say that induction heating, because it does not heat anything other than the object you want to heat, is an admirable thing at the point of use; but the use is of inefficiently generated electricity. The example is one of avoidance of using a wrong fuel for a given purpose or avoidance of the use of a fuel where none should be used. In other words, I agree that the case he has made is correct, and respectfully claim that it fortifies my argument.

THE CHAIRMAN: I think that we have had a very long and useful discussion, and that it is time we closed. May I, therefore, thank the lecturer very much for his lecture: he has seen what interesting discussion he has stimulated. May I ask you to show your appreciation in the usual way?

The vote of thanks to the Lecturer was carried with acclamation; and, another having been accorded to the Chairman, the meeting ended.

The following contributions to the discussion have been received since the meeting, at which there was no opportunity to make them:

MR. DONALD V. SMITH: With the lecturer's general thesis I think all his audience agreed, but I wish to comment on a suggestion he made towards the end of his paper,

i.e. the example of a power station design for a combination of power, district heating and heat pump. Even with the first two only, an efficiency of over 70 per cent can be obtained and there are many towns in Britain where the central areas could be so supplied, and it would not perhaps be so extravagant in capital cost as Mr. Johnson suggests. Most of the more inefficient power stations are to be found already in many of these areas; according to the British Electricity Authority reports there are nearly 200 with efficiencies of less than 12 per cent. In many of the same areas there exist factories and warehouses requiring heat and process steam, while adjacent are old and condemned housing areas for which plans are already proposed for new flats, so that here is an opportunity for combining a far higher standard of modern domestic heating with a modernized and more efficient power station.

The total capital cost of a combined heat and power station, in such conditions, would be less than the cost of the individual boiler and heating systems plus the equivalent cost of the equal capacity of the condensing power station.

The suggestion of one speaker, if I heard correctly, that the existing type of power stations should be trebled in total capacity, involving a potential waste of nearly 70 million tons of fuel, should have horrified the audience.

I was astonished to hear Dr. Parker's comment on district heating, that these systems are more costly in fuel consumption than individual systems, and I most emphatically controvert this. There are numbers of such systems, both on the Continent and in the United States, some combined with power stations and others for heating purposes, where the economy in fuel, as against individual systems, has been abundantly demonstrated.

If Dr. Parker would study the recent handbook published by the National District Heating Association of America, he would find ample factual evidence to controvert his statement.

In Great Britain there are about a dozen of such systems, but mostly on a very small scale, all started during the past few years. Of these twelve, three are too small to afford much reliable data, although they are no doubt useful and should give some guide as to what to avoid as well as what to repeat. At least seven of the others have been so drastically curtailed, nearly all after the original plans were accepted in principle and the work started, as to seriously prejudice and affect their economical operation. Only two or three of the smaller schemes are completed, and I feel Dr. Parker's comments must have been made on the preliminary reports of the results from some of these systems, some of which may suffer as much from unsatisfactory operation as unsuitable application.

Two things are necessary to form a fair judgment on district heating, and these are as follows:

1. The schemes must be designed for *suitable* areas.
2. They must be operated efficiently and economically, and not used lavishly and wastefully, as some of them are to my knowledge.

Given suitable design and operation, there can be no doubt that district heating schemes could be economical, both in fuel consumption and cost.

This, however, is not wholly an engineering problem. Town Planning Authorities must co-operate and so far, in nearly all cases, the engineer is given no chance until it is too late. So long as public authorities in this country act as extreme individualists, and housing and town planning authorities plan, or execute their plans, in penny stages, while the British Electricity Authority think and act in hundreds of millions, just so long will our total heat and power requirements continue to mount in cost and the existing inefficiencies remain.

If real co-operation could be obtained, I venture to say that the total capital cost would be no more than our present inefficient methods cost, while operating costs could definitely be reduced.

MR. G. VIVIAN DAVIES, A.M.I.MECH.E., F.INST.F.: I should like to question Mr. Johnson's statement that fuel economy involves heavy capital outlay. This is not so in every case.

As far as industry is concerned there are still big savings to be made by more effective administration of large fuel-using plants such as better arrangement of equipment and improved process operation, but this usually means giving the fuel technologist an improved status.

On the domestic and commercial side, most of our large buildings are grossly overheated, and architects and heating engineers seem to overlook the heat given out by the human body, which is considerable.

There are numerous periods of mild weather during the heating season of November to April, when heating could be shut off or considerably reduced. We find heating plants operated to full capacity and the occupants of such buildings living in an atmosphere resembling a Turkish bath, yet nobody seems to do anything about it.

Intelligent use of the radio and weather forecasts should make it quite a simple matter to regulate heating by temperature and not by date. Thermometers and thermostatic controls are comparatively inexpensive items of equipment.

Then again, proper insulation of new buildings, including private houses, adds very little to the initial cost, but cuts down the fuel requirements considerably.

It was found during the war that prolonging summer time throughout the winter months just when it was most needed effected an appreciable reduction in fuel consumption. Yet as soon as the war was over we returned to our old habits.

Large-scale capital expenditure to save fuel also takes a long time and we cannot wait. The British Electricity Authority's ten-year expansion plans involve using about the same amount of coal as the National Coal Board's ten-year development plan is expected to produce.

Therefore the increased fuel required for industrial and commercial development can only be found from economies effected in the ways I have indicated.

Mr. Johnson has made the following comment on Mr. G. Vivian Davies' contribution:

I am largely in agreement with Mr. Vivian Davies' remarks, but regard the expedients mentioned as being too superficial to have a serious effect, for which, I maintain, capital expenditure is necessary.

A CENTURY OF PHOTOGRAPHY

The Peter Le Neve Foster Lecture by

I. D. WRATTEN

President, Royal Photographic Society, delivered on Wednesday, 4th February, 1953, with E. Munro Runtz, F.R.I.C.S., Chairman of Council of the Society, in the Chair

THE CHAIRMAN: Just over a fortnight ago, on January 20th, many of us who are here to-day were gathered in this room under the auspices of the Royal Photographic Society and under the chairmanship of their President, Mr. Wratten, to celebrate the centenary of that Society, which had been born in this building a hundred years before to the day and hour. At that meeting, Mr. Sinkinson, the President-elect of that Society and a Fellow of our own, who is here to-day, gave us an interesting account of the history of his Society during the intervening hundred years.

To-day we are honoured by the presence here as our lecturer, of Mr. Wratten, and I should like to take the opportunity which I have as Chairman this afternoon to repeat my congratulations to his Society on its splendid record of achievement which has always been watched with admiration by our own Society and in which we have, from time to time, had an opportunity to share.

As I think we all know, the Society of Arts was making a notable contribution to photographic history at the very time when the Photographic Society was born within its walls by holding in this room the first specially organized Exhibition of Photography. That exhibition lasted from December 26th, 1852, to January 29th, 1853 (it was actually in progress at the time that the Photographic Society was founded), and in view of its great success it continued in the form of a travelling exhibition which went all over the country.

After that, the Society was honoured to have as lecturers many of the most notable authorities on photography, such as Watkins, the inventor of time development, and Beck and Dallmeyer, the optical experts, and above all, Sir William Abney, who lectured to us on many occasions and was both President of the Royal Photographic Society and Chairman of Council of the Royal Society of Arts.

In more recent times we have been privileged to listen here to men so eminent in the photographic world as Dr. Kenneth Mees and Dr. Spencer, and I must not leave unmentioned the meeting we held in celebration of the Centenary of Photography in 1939, when our platform was shared by Dr. Olaf Bloch, Miss Matilda Talbot and Mr. Dudley Johnston.

There are two aspects of photography in which the Society of Arts has taken a particular interest. The first of these is colour photography, on which many well-known pioneers, from F. E. Ives onwards, have contributed papers to our Society. The other is cinematography, to which we were first introduced in 1882 by the American, Muybridge, who showed moving photographs of animals with his famous Praxizooscope. Another notable lecture in that field was by G. A. Jones in 1908, who showed here what I believe was the first two-colour cinematograph film. But the occasion of which we are proudest was the meeting here in November, 1924, when Mr. C. F. Elwell read a paper on the de Forest Phonofilm and gave the first public demonstration in this country of the "talkie" film.

However, we have not come here this afternoon to hear a recital of the good deeds

of the Royal Society of Arts. We have come here to commemorate the work for our Society of Peter Le Neve Foster, who became Secretary of this Society a hundred years ago this year and continued to be its Secretary until 1879. There can, I think, be no more appropriate way of honouring his memory this year than by recalling his association with the early days of photography, for he was one of the first to experiment as a scientific amateur with the new art and he was one of the founders of the Photographic Society. It is interesting, too, to recall that his successor, Sir Henry Trueman Wood, was also a noted photographer and President of the Royal Photographic Society from 1894 to 1896. I am sure that Peter Le Neve Foster would have been highly gratified had he known that at the centenary of the beginning of his secretaryship a lecture would be delivered in his memory on a subject in which he had taken so keen an interest, and that it would be delivered by the President of the important society which he had helped to found.

I therefore have great pleasure in calling upon Mr. Wratten to deliver the Peter Le Neve Foster Lecture for 1953.

The following lecture, of which the first part was illustrated with a colour film made for the occasion, and the second part with lantern slides, was then delivered:

THE LECTURE

It is appropriate enough, when the Royal Photographic Society has reached its hundredth year of existence, that some attention should be paid to the progress of photography itself during the period of the Society's existence. That the Royal Society of Arts should invite the President of the Royal Photographic Society to deliver the Peter Le Neve Foster lecture on this subject is a compliment which we of the R.P.S. greatly appreciate.

The scope of photography is now so wide that the subject presents many difficulties, in terms of presentation, and I am greatly indebted to Dr. C. E. K. Mees and Dr. Walter Clark, who have given me so much help that this lecture is really theirs and not mine.

The first photograph of which there is any definite record was taken by Nicéphore Niepce in 1826 upon a polished pewter plate coated with bitumen of Judea, which becomes insoluble after prolonged exposure to light. This photograph was recently found by Mr. Gernsheim and has been reproduced in the newspapers.

Photography as a widely practised art dates from 1839, when Louis Daguerre and Fox Talbot published their processes, known as Daguerreotype and Calotype, respectively. Modern photography, however, does not utilize to any appreciable extent the discoveries of Niepce or even of Daguerre. Almost all processes employed at the present time depend upon the sensitiveness to light of silver bromide suspended in gelatin.

One hundred years ago the process in use was known as "wet collodion", the process having been introduced in 1851 by Scott Archer. The photographer coated his glass with a solution of nitro-cellulose in ether and alcohol containing iodides soluble in alcohol, and immersed the coated plate in a tank containing silver nitrate solution, which precipitated silver iodide in the film. After exposure, which lasted a second or more in bright light, the plate was developed immediately with an acid reducing agent, which precipitated the silver upon the exposed

iodide particles, and the remaining iodide was dissolved in cyanide solution. After a brief washing, the thin film was dried rapidly and the negative was ready for printing upon the albumenized printing paper, which is described later.

In 1871 W. L. Maddox replaced the collodion by a solution of gelatin, and the use of gelatin to hold the light-sensitive silver halide eventually resulted in the gelatino-bromide emulsion process, which by 1880 had replaced the wet collodion process for most photographic work. Since then, the gelatino-bromide emulsion has been improved greatly in sensitiveness and in uniformity. The sensitiveness of the modern negative-making materials is such that a clearly defined impression is produced upon them by exposure to the light of a candle at a distance of one meter for only one hundredth of a second. Nevertheless, the negative emulsions of the present day are essentially the same as those made seventy years ago.

The sensitive emulsion consists of a suspension of crystals of silver bromide containing a small percentage of iodide in gelatin. The crystals are well defined, usually hexagonal or triangular in shape, belong to the cubic system, and occur in the form of flat plates with their faces horizontal, the drying of the emulsion causing the crystals distributed in all directions in the original emulsion to form an approximately flat series of layers.

The crystals which actually occur in an emulsion are very varied in size, a fast emulsion containing a complete range of crystals, from those of ultra-microscopic size below one-tenth of a micron in diameter to crystals five microns across. Since the exposure to light of any portion of a crystal renders the entire crystal developable, it is clear that a much greater mass of silver is produced by the exposure of a large crystal than of a small crystal, the same amount of light or approximately the same amount of light making either a large or a small crystal developable. Further study has, however, shown that the sensitiveness of the crystals is not uniform over the whole surface but that the sensitiveness appears to reside in specific spots or centres of sensitiveness distributed on the surface of the crystal. At the beginning of development corresponding spots of reduced silver are formed, and these continue to grow at the expense of the silver bromide of the crystal until the whole of the crystal is reduced to a mass of silver occupying approximately the same position as the original crystal and, if the latter were sufficiently large, being of approximately the same form.

Very large amounts of silver are used in the manufacture of photographic materials at the present time, the total consumption of silver for this purpose being about twenty tons a week, which is about one fifth of all the silver mined in the world. The consumption of bromine is also very important, the photographic industry being one of the very largest consumers of bromine.

The negatives made in the camera must be printed upon a suitable paper to produce a photograph. The early dry plate negatives were printed upon albumenized paper; that is, paper coated with albumen containing chloride and sensitized by immersion in a bath of silver nitrate so that the sensitive layer consisted of a suspension of silver chloride in albumen. This was printed under the negative by daylight, and the image was toned with gold. The albumen paper

process was followed by other "printing-out" processes, as they were termed, such as the gelatino-chloride process. Printing processes, however, have been far more diverse than negative-making processes. The sensitiveness of bichromate to light was discovered by Mungo Ponton as long ago as 1839, and in 1864 gelatin sensitized with bichromate was worked out as a practical photographic process for making prints and was placed on the market under the name of the "carbon" process by Joseph Wilson Swan.

Processes depending on the reduction of ferric oxalate in the presence of light have also been used, and one of the most ingenious and beautiful adaptations of this process was that employed by W. Willis in 1873 for the production of images in platinum, the paper being coated with a mixture of potassium chloro-platinite and ferric oxalate. On exposure to light, the ferric oxalate is reduced to ferrous oxalate, and when the exposed print is immersed in a solution of potassium oxalate, the ferrous oxalate dissolves, forming a reducing solution which then reduces platinum *in situ* from the chloro-platinite and thus produces an image on the paper consisting of black metallic platinum, which has extreme permanence. The image is also of very good gradation so that platinum prints made in this way are among the most beautiful ever made and enjoyed great favour for many years. The great increase in the cost of platinum has made the process almost impossible economically, and very few prints are now made by means of it.

The present tendency in printing processes is away from those which depend on large amounts of light—those which require printing-out by means of daylight—and is toward those processes which use an artificial light source. Silver bromide emulsions are coated upon paper and used under the name of "bromide" paper, which is used when images are printed by projection, the sensitiveness of the paper making it possible to enlarge the image without any very powerful lenses or light sources. A great advance in the production of developing-out papers was made when Baekeland in 1894 for the first time made a paper from which he did not wash out the residual salt, the paper containing silver chloride in a suspension of gelatin. After a brief exposure to artificial light, the paper is developed in the same way as a bromide print. This first chloride paper has been followed by a great variety of papers of the same type. Nowadays these slow "developing-out" papers, as they are called, are used not only by amateur photographers but for almost all professional printing.

In the early days of photography, all the negative materials used were coated upon glass plates. Though glass plates have the advantage of rigidity and permanence, they have the disadvantage of considerable weight and of risk of fracture, and their rigidity makes it difficult both to manufacture them and to use them in the field in small and convenient containers.

After attempts had been made to replace the rigid glass plate by paper coated with a silver bromide emulsion which could be printed by making it translucent to light or from which the image could be stripped together with the gelatin coating, there was evolved the flexible film in which the emulsion was coated upon a base composed chiefly of nitrocellulose, which is flexible, transparent, and inert towards the emulsion. With the production of the flexible film

there came a very great change in photography. Instead of the cumbersome and heavy glass plate outfit, extremely small and portable cameras could be used. They carried rolls of flexible film which before long were made so that they could be inserted in and removed from the camera in daylight, thus enabling a large amount of photographic material to be carried in a small space without special holders.

Whereas in the earlier days of photography amateurs manufactured their own material, cleaning their glass plates and then coating them with collodion, sensitizing them, exposing them, developing them, and then coating paper with albumen and sensitizing it, printing it, and finishing it; with the introduction of the gelatino-bromide process and dry plates, which retained their light-sensitive properties for a reasonable time, the production of the negative materials and then of printing materials was taken over by manufacturing firms who produced the materials in large quantities and sold them to the users. With the introduction of roll-films a further stage in this transition occurred, and it became customary for photographers not only to buy their materials from the makers but also to leave the finishing of the pictures to professional experts, they themselves only taking the photograph in the camera and then turning over the exposed spools to a firm who would develop them and make prints, usually upon gaslight papers. This developing and printing business has now become a large one throughout the world. Not only are a great many photographic dealers engaged in the finishing of amateurs' photographs, but there are many firms who make this their sole business.

The great success which followed the introduction of roll-film for amateur use suggested, of course, that films might also be found useful in professional photography for the taking of portraits. The introduction of films into this field was delayed for some years by the necessity for providing quite different equipment from that required for glass plates. The plate holder, in which the rigid glass plate was supported, had to be replaced by special film holders, and at the same time the developing apparatus had to be made convenient for handling flexible material. At the present time, it seems inevitable that flexible film will displace rigid glass plates for all purposes except where extreme rigidity of the support is necessary in order that no possibility of shrinking or swelling may exist. In astronomical photography, for instance, where the positions of stars are measured, it is most important that the image should remain rigidly in position and that no displacement should occur. In such work, glass plates still reign supreme.

The production of flexible film for roll-film cameras also made possible the production of motion pictures. Motion pictures are produced by taking a great number of photographs successively, usually at intervals of a twenty-fourth of a second, and these pictures are then projected successively in the same manner upon a screen so that the images blend into each other by persistence of vision and the objects photographed appear to move upon the screen. The production of such a series of images upon glass plates would not be quite impossible, but it would have been very difficult, and it was the development

of the flexible ribbon of celluloid which made it easy to produce this result. At the present, over the whole world, more than a thousand miles a day of celluloid ribbon are produced for use in motion pictures chiefly, of course, for amusement purposes. These ribbons are now made of cellulose acetate plastic about five thousandths of an inch thick and one and three eighths inches in width. They are driven through the cameras and projection machines by means of perforations along the edge, the position and size of the perforation, as of the film itself, being very carefully standardized with international specifications.

There is no need to dilate here upon the immense ramifications of the motion picture industry, but it is worth while to remember that the industry is specifically a branch of photography and can only progress and develop by the production and improvement of photographic processes.

Though motion picture photography developed in the closing years of the nineteenth century, no satisfactory method for the taking of motion pictures by the amateur was available until 1923, at which time small portable cameras and narrow width films to supply them were introduced. The use of the standard professional motion pictures for amateur photography was difficult partly because of the very high cost, partly because of the size and clumsiness of the apparatus required, and partly because of a lack of facilities for developing and printing the films taken by amateurs, the professional laboratories being organized with a view to the special demands of the motion picture trade. It was also important that the films used by the amateur should be of the slow-burning type. It would have been most unsafe to use in private dwellings the nitrocellulose film used in the theatres. This was overcome by the production of film made of cellulose acetate, which is quite safe for general use, and this film was returned to the dealer or manufacturer for processing after it had been exposed. To simplify the processing and diminish the cost, the film exposed in the camera was converted into a positive. This would be unsatisfactory in the case of professional films, where many copies are wanted, but as a general rule only one copy is required for each picture taken in amateur cinematography, and if more are wanted, it is possible to make duplicates.

The Pathé Baby film introduced in France was 9·5 mm. in width and took forty pictures to the foot. The 16 mm. film introduced in the United States and Great Britain also takes forty pictures to a foot. In 1932 a method was worked out by which two rows of pictures were taken on the 16 mm. film, each of them a quarter of the size of the 16 mm. picture, the film being slit down the middle after processing, so that the finished film is 8 mm. wide and carries eighty pictures to a foot. This greatly lowered the cost and made the taking of home movies a widespread pastime.

About eighteen years ago, methods were found for making photographs in colour by a new process applying the principles of colour photography to produce a colour picture with a minimum of difficulty for the user. The new colour film was made by coating three emulsion layers over each other so that each layer records one of the primary colours. The images so recorded were then converted into positive dye images, the picture taken by red light yielding

a blue-green positive; the one taken by green light yielding a magenta positive; and the one taken by blue light a yellow positive. The three colours are superimposed in exact register in the film and are not seen as separate colours, so that a direct colour positive is obtained upon the film exposed in the camera. This process was quickly adopted for amateur cinematography, for which it was exceptionally suitable, since, in the case of the black and white pictures, the camera film was used for projection and the processing was done in organized laboratories as a commercial operation. At the present time a very large proportion of amateur motion pictures are in colour.

Soon after the new colour film was introduced for motion pictures, the same principle was applied to the small pictures taken in cameras using 35 mm. film, and again the use of colour film is proving very successful. The customer buys the roll of colour film and loads it in the camera. After exposure, it is returned to the maker, who transforms it into colour positives and returns the positives in small cardboard mounts ready for projection. This process of photography is very different from the processes which have flourished during the last hundred years—in as much as the pictures are direct positives, copies are not easily available, and the pictures must be projected for viewing—but there is every indication that the process will have a very wide use. Experience has shown that a very high proportion of all these pictures gives results satisfactory to the photographer.

Colour photography is growing at a very rapid rate. It is not yet clear what system will be used for colour portraiture. Films fitting the ordinary roll-film cameras are being made which give complementary colour negatives when they are developed, and these can be printed upon a three-layer paper to give colour prints. Professional motion pictures have for many years been made in colour, and there are clear signs that before long the majority of such pictures will be made in colour. On the whole, therefore, the photography of the past was in black and white; the photography of the future will be in colour.

Photography has had a profound effect on present-day affairs. Its impact on the progress and well-being of mankind has been as great as that of many other factors significant in recent history. At the close of a century of existence of the Royal Photographic Society it might be of interest not only to trace the progress of the processes of photography, as we have just done, but to recall some of the things it enables us to do to-day.

The ability to take photographs is at the disposal of all who can do the simplest of operations. Not only can snapshots be made with the minimum of knowledge and effort, but so also can motion pictures and colour slides. One of the things which has made photography so popular for the bulk of the people is the D. and P. system, which "does the rest" after the photographer has pushed the button. This is particularly true in the case of colour film, which in the form in which it is used by amateurs is very difficult to develop.

The portrait photographer has been a familiar figure through the century, and, as we have pointed out, the interest in portraits provided the great impetus which carried photography forward in its earlier years. To-day, the studio of the professional portrait photographer is a very different matter from what it was

before the introduction of high speed films and modern lighting and the great variety of techniques and printing papers. Some portraiture is done on a mass production basis, but in most cases portraits are handled individually.

The main purpose of the press photographer is to make pictures with the greatest popular appeal as soon as possible after an event has occurred. The ultimate objective is the "scoop," which is the obtaining of the first and perhaps unique picture of an event of great public interest. It is sometimes a matter of planning, frequently a matter of audacity, and largely a matter of chance. The present day picture paper relies on the press photographer for most of its illustrations.

Another professional is the commercial photographer, who makes photographs for advertising in posters, magazines, leaflets and so on, takes pictures of factories and manufacturing operations, and makes a great variety of photographs of high quality to bring out special points. The public sees most of his work in the form of printed advertisements, and he therefore exercises much influence on public taste.

The public knows its photographs from snapshots and portraits and newspaper and magazine illustrations, but probably as much as anything from the films in the cinema, most of which are made for entertainment purposes. They represent a high achievement in photographic technique and a very large industry. Colour film with sound accompaniment is available in a variety of forms, but it owes its popular success mainly to the Technicolor Company. Probably the television industry will require a large amount of film, because it appears that the bulk of television programmes in the future will be from film rather than from live acts. Television can go hand-in-hand with the film industry in another sense in that it is possible to photograph the picture-tube image in a motion picture camera in a theatre booth, develop the film by rapid-processing techniques, and project the film on to the theatre screen, so providing a method of screening news events.

Recently much study has been devoted to ways of copying documents. The systems similar to the well-known Photostat method are designed to give a faithful copy of a document in a reasonable time and of good stability. Original copies in the past have been with white characters on a black ground, but there has recently been produced a paper which gives a copy with black letters on a white ground. Machines are available in which the development of the paper is done on the machine in which the document is copied, so that the whole system is automatic.

Document reproduction methods have come into vogue in which the main purpose is to have a paper copy in the shortest possible time. There are several of these systems which depend on developing an image in an emulsion on paper and transferring part of it or a reacting agent to a receiving sheet.

A great amount of document copying is done on film, primarily to save storage space. The Recordak system for copying cheques in banks uses 16 mm. film. The Micro-File system, which uses special cameras and 35 mm. film, is now a standard technique for copying printed matter, drawings, and other subjects to give small-size negatives from which enlarged prints can be made. The

ultimate in space reduction is accomplished in systems by which as many as twenty pages can be printed on one three-by-five card and read with special optical projection viewers.

Photography has long played an important part in the field of printing. Special films are used for making half-tone and line negatives for printing pictures and line drawings, and techniques have been worked out for improving colour reproduction in printing processes. Lithography offers the greatest opportunity for photography and is rapidly gaining over other ways of photo-mechanical reproduction. One of the most significant advances has been in the technique of composing type by exposing film instead of casting in metal. There are several so-called photographic composing machines in use at present—the Westover system in this country and the Foto-setter and the Photon machines in the United States. It appears that photographic type composing will be more and more used for printing by lithography and relief. Electro-optical "scanners" have been devised in which colour-separation negatives for colour reproduction can be made with correction for the deficiencies of the printing inks and the printing process. Good printing, even of colour subjects, is now being done on small lithographic presses, and magazines and newspapers can be printed by lithography on special web presses in colour.

In the fields of science and technology, photography has come to be an indispensable means of investigation and recording. It is useful because it enables permanent records to be made for later study, it permits the slowing down or stopping of events which occur so rapidly that they cannot be studied by the eye, it will record things that are too faint to be seen by the eye because on long exposure recognizable images can be obtained, and it will give a visible record of radiations which the eye cannot see.

One of its most important uses is in the photography of the spectrum, because the positions of spectral lines are fixed in relation to the structure of matter, and photography of the spectrum can therefore be used as a means of determining the composition of materials. This is particularly significant in the case of astronomy, where the stars and planets are not available for direct analysis and can only be studied through the radiation that they emit.

Without photography our knowledge of the universe would be very much restricted, and present-day astronomical telescopes are built for photography rather than for visual observation. There are now very extensive astronomical projects under way using cameras of new design intended to give shortened exposure times and to cover large areas of the sky. Large cameras of the Schmidt type are being used for mapping the sky, and wide-aperture telescopes, represented in the extreme by the 200 inch on Mt. Palomar in California, probe the outer depths of space.

One of the most important of the applications of photography in recent years has been in the study of the ultimate structure of matter and the transmutation of the elements. Special photographic plates free from fog and using thickly coated emulsions in which the concentration of silver salts is very high are bombarded with cosmic rays or with the beams of particle accelerators.

Some of the atoms in the plate may violently disintegrate and shoot off component particles which travel through the plate, affecting the silver salts so that when the plate is developed, the trails of these new particles show up as lines of silver grains. If special fissionable materials are put into the emulsion, bombardment with neutrons may produce tracks, and electrons and α-particles will produce tracks directly.

Radioactivity was discovered by Becquerel in 1896 as a result of putting a piece of pitchblende on a photographic plate. After development an image appeared on the plate and it was proved to be due to the presence of radioactive materials. This is the original classical experiment which has led directly to our studies in the field of nuclear physics. The actual technique used by Becquerel is now employed very extensively for obtaining what are known as autoradiographs. They are of particular interest in biological studies to determine the distribution of elements in tissues. Radioactive isotopes of elements such as iodine or phosphorus may be injected into an animal and taken up by the tissues. If microsections of such tissues are placed in contact with a plate or film, the radiations given off produce, as it were, a self-portrait of the section, and from this the distribution of the radioactive elements may be determined.

The discovery of X-rays by Roentgen in 1895 opened up a field which is one of the most important applications of photography at the present time. X-rays are applied to study the internal structure of objects which are too opaque to be looked into and of which sections cannot be made. The greatest use of radiography is in the field of medicine, where far more X-ray pictures are taken each year than are portraits by the professional photographer. Medical radiographs provide an important means for diagnosis, an easy way of locating foreign objects, the position and extent of fractures, and a great many other things of interest to the doctor and therefore to his patient. By diffracting X-rays through crystals and recording the pattern on film, the arrangement of atoms in molecules may be determined, and X-ray spectroscopy is a well-established means of scientific investigation.

Radiography has also had an important application in the industrial field, in that it permits the study of the internal structure of opaque materials, in particular manufactured metal objects. X-ray machines operating at voltages up to two million have now been made commercially in order to enable photographs to be made of thick metal objects with reasonably short exposure times. Other devices are now being developed for producing even more penetrating X-rays. Sometimes a radioactive source of radiation is used instead of X-rays. Radiography can also be used for investigating the structure of small objects. In this case, X-ray photographs are made on fine-grain films which are then enlarged in the conventional way.

In the medical field in general, both black-and-white and colour photography are being more and more used for recording case histories, for the study of pathological conditions, and for many other applications.

Photography by invisible radiations is, of course, well represented by radiography, nuclear track photography, and spectrography, to which we have already

referred. It has long been possible to take photographs by means of the invisible infra red radiations which lie just beyond the red end of the spectrum. One of the most spectacular of the early infra red photographs was made by Sir William Abney when he photographed the spectrum of the sun out to beyond 10,000 A. Interest in infra red photography was confined largely to physicists and astronomers until about 1930, when ways were found by which infra red-sensitive films and plates could be made having a speed which permitted their use with the simplicity of ordinary photography. Infra red photography has proved to be useful in criminological investigation, medical and aerial photography, and in a number of other fields.

One of the properties of infra red is that by virtue of its long wave length it can penetrate certain types of atmospheric haze, thus showing distant detail. Advantage of this is taken in long distance photography from the ground, for example, the German photographs during the war of the radar towers on the south British coast from the Pas de Calais, and in aerial photography, where the presence of haze tends to obscure ground detail. In its other applications infra red photography depends on the fact that the infra red is reflected or transmitted by objects in a manner different from visible light, and on this basis it has been used in camouflage-detection studies, investigations of falsified documents, study of restored paintings, plant pathology, palæontology, and the textile and graphic arts industries.

Since infra red is invisible, it should be possible to take photographs in total darkness, and this has been done using hot objects, such as electric heaters, and also using incandescent lamps from which the visible light has been screened by suitable filters.

Photography through the microscope is very important in biology, metallography, petrography, and in the study and determination of the sizes of small particles. In the case of biological and geological subjects, the samples to be photographed in the microscope are usually cut into very thin slices and, in the case of biological sections, stained by means of dyes. Photomicrographs are often made by polarized light, particularly in the case of geological specimens. Sometimes the photographs can be arranged so that the objects appear white on a dark background instead of in the conventional manner. In the case of metal specimens it is common practice to make flat surfaces, polish them, and etch them chemically. Colour photography is being more and more used in photomicrography.

The detail which can be photographed through the conventional microscope is limited by the wavelength of visible light. Higher resolution can be obtained by using ultra violet, but the greatest magnifications of detail are possible through the use of the electron microscope, which has been developed in recent years. Magnifications up to 100,000 diameters may be obtained by making photographs in this instrument and enlarging the negatives, and this technique has permitted the study of things which a few years ago could not be seen with the best visual microscope because of their small size, such as viruses and the fine surface structure of metals. Special techniques, such as casting shadows by gold and

making replicas of surfaces in thin plastic films, have permitted many striking and very important electron micrographs to be made. Electron micrography is now a standard tool in industry and science.

The pace of a racehorse is but a mere dawdle compared with that of many of the things that move about us to-day, but even in racing, photographs taken at very short exposure times are frequently necessary to decide the winner and satisfy the betting public. A problem like this is fairly easy, because the exposure time required to stop a horse at racing speed is not particularly short. Not so, however, where it is necessary to study the behaviour of a bullet in flight or the course of combustion in an explosion or the operation of a cutting tool on a high-speed milling machine. In all such cases the only way to study the phenomenon is to use ultra high-speed photography.

There is a limit of about one thousandth of a second to the speed of a conventional type of shutter. In order to obtain short enough exposure times to stop the motion of very fast moving events, it has been necessary to resort to electric sparks and other special electrical discharges which give out a lot of light of very short duration. These photographs may be shadowgraphs, which show the outline but no detail, or reflected light pictures, which show the details of the subject. In order to photograph bullets in flight, bright electric sparks giving exposures of only one millionth of a second are required. Explosions give off their own light, and this may be used in direct photography of the flame to give a record of its development. Supersonic phenomena are now able to be studied by the high-speed camera, for the shock wave can be photographed directly or in an instrument known as the Mach interferometer.

High-speed pictures are made as single photographs, as a short sequence of separate photographs, or as a long sequence of pictures in a high-speed motion picture camera. One of the most interesting of the recent applications of high-speed photography is in the field of radiography, in which X-rays are used instead of light, permitting a study of high-speed phenomena in opaque objects.

Photography from the air was done in the later part of the last century by sending up cameras in balloons and kites. During the First World War the art of aerial photography for military purposes was developed on a very large scale. In modern war it is the means by which most of the information about the enemy is derived. Since the First World War the use of aerial photography increased very greatly as a means of providing the information for making maps, both for the construction of new maps and the revision of old ones. During the Second World War and in the Korean conflict, aerial photography has been used on a vast scale for reconnaissance in enemy territory to show troop and material movements, the location and details of prospective targets for bombing raids, recording the results of bombing and other attacks, observing the construction of highways, bridges, docks, and industrial plants—in fact, for obtaining the vast amount of information about the enemy that is needed for modern military operations.

Modern military aerial photography is done from very high altitudes or from low altitudes in fast flying planes, in black-and-white and to some extent in

colour, making series of overlapping pictures or continuous strips of pictures which can later be used for the identification of objects on the ground and in some cases for plotting maps. Aerial photographs can be made at night by using special high-intensity flashes. Topographic photography from the ground using precision cameras after the manner of surveying instruments is still done to some extent in mountainous areas, but the bulk of survey photography is done from the air.

In addition to its uses in military reconnaissance and mapping, aerial photography is being used for forestry and geological survey, for traffic surveys in busy cities, to determine the location of oil pipe lines, electrical transmission lines and cross-country highways, to measure the areas of crops in farming country, to study soil erosion, to count seals and shoals of fish, to determine underwater features, and a variety of other purposes.

It will be evident to the listener that the applications of photography are without limit and that each day brings a new crop. Only a few of the most significant have been mentioned here. Photography is one of the most important tools in modern scientific, technical, and business progress as well as in the entertainment and instructional fields. The work that is done by the scientist, even in his relatively restricted field, cannot fail to have an influence on photography on the whole and therefore benefit all users of films and cameras. On the other hand, the constantly increasing interest and demands on the part of the general photographer result in improvements which cannot fail to benefit the scientist and technologist. In the over-all picture, any progress in any part of photography must benefit the whole.

At the end of the first hundred years of existence of the Royal Photographic Society, and to a great measure through the influence of the Royal Photographic Society, photography has attained a stature undreamed of at the start. It does not seem to be destined, at least in the foreseeable future, to be replaced by any other recording medium in its wide ramifications.

MR. PETER LE NEVE FOSTER (A Vice-President of the Society): It falls to me to propose a vote of thanks to Mr. Wratten. I feel very honoured to have been asked to do this because I have a threefold interest in this afternoon's meeting. I am the great grandson of Peter Le Neve Foster in whose memory this lecture has been given, I am a Vice-President of this Society, and I am one of the older members of the Royal Photographic Society. I find it difficult to know whether to thank Mr. Wratten most for his lecture, his film or his slides. They have all been so interesting that I think it would be invidious to draw any distinction between them. I feel that anything that I can say can only come as an anti-climax after the lecture and these really magnificent pictures, and so without wasting any more words, I have pleasure in proposing a vote of thanks to Mr. Wratten.

The vote of thanks to the Lecturer was carried with acclamation and the meeting then ended.

FROM THE JOURNAL OF 1853

VOLUME I. 11*th March*, 1853

From Home Correspondence: Photography; *from* Henry W. Reveley

As my only object is the improvement of the photographic art, I shall take this opportunity of making one or two suggestions with that view. First, I should wish that the photographic camera could be constructed of such a size that the photographer could place himself inside, with a stool and shelf, upon which he might perform the whole of the manipulations; and that the sensible tablet should not come out of the camera until it was completely fixed. On the outside of the camera there should be a yellow glass lantern with reflector, showing a light inside. There should also be sliding shutters fitted to it inside, as well as to the object glass; and, of course, the camera should be well and thoroughly ventilated. It will be said that there are formidable obstacles to such a procedure; but what *would* have been said fifty years ago to the proposer of a sub-marine electric telegraph, or of photography itself?

Some Meetings of Other Societies

MON. 9 MAR. Electrical Engineers, Institution of, Savoy Place, W.C.2. 5.30 p.m. *Is the Presentation of Technical Literature Adequate?* (Discussion).

Geographical Society, Royal, S.W.7. 5.30 p.m. *Western Nepal* (Films).

Imperial Institute, S.W.7. 5.30 p.m. Mrs. Bertild Bekker: *The Colonial Empire: Borneo and Hong Kong.*

TUES. 10 MAR. Manchester Geographical Society, 16, St. Mary's Parsonage, Manchester, 3. 6.30 p.m. Norman Pye: *Arizona.*

Mechanical Engineers, Institution of, Storey's Gate, S.W.1. 5.30 p.m. Harold Drew: *Engineering Changes.* Photographic Society, Royal, 16, Princes Gate, S.W.7. 7 p.m. P. W. Harris: *Review of Photographic Apparatus and Literature.*

WED. 11 MAR. British Kinematograph Society, at Film House, Wardour Street, W.1. 7.15 p.m. Norman S. Macqueen: *Unusual Achievements in 16 mm. Film Production.*

Electrical Engineers, Institution of, Savoy Place, W.C.2. 5.30 p.m. E. McP. Leyton, E. A. Nind and W. S. Percival: *Low-Level Modulation Vision Transmitters, with special reference to the Kirk O'Shotts and Wenvoe Stations.*

Petroleum, Institute of, 26, Portland Place, W.1. 5.30 p.m. T. T. Scott: *The International Labour Office and the Petroleum Industry.*

Photographic Society, Royal, 16, Princes Gate, S.W.7. 7 p.m. B. G. A. Snelson: *The Fenland Scene.*

Victoria & Albert Museum, S.W.7. 6.15 p.m. Charles H. Gibbs-Smith: *The Wellington Museum, Apsley House.*

FRI. 13 MAR. Mechanical Engineers, Institution of, Storey's Gate, S.W.1. 5.30 p.m. A. M. Sage: *Steels for Steam Power Plant.*

SAT. 14 MAR. Horniman Museum, Forest Hill, S.E.23. 3.30 p.m. J. V. Jansen: *Art in the Life of a Melanesian People.*

MON. 16 MAR. Geographical Society, Royal, S.W.7. 8.15 p.m. W. Q. Kennedy: *The Mountains of the Moon.*

Imperial Institute, S.W.7. 5.30 p.m. Mrs. E. S. Rutter: *The Colonial Empire: Western Pacific.*

TUES. 17 MAR. British Architects, Royal Institute of, 66, Portland Place, W.1. 6 p.m. H. V. Lobb: *Successes and Failures of New Techniques.*

British Kinematograph Society, at Film House, Wardour Street, W.1. 7.15 p.m. Esther Harris and Arnold Williams: *The Production and Distribution of Trailers.*

Industrial Transport Association, at the Royal Society of Arts, W.C.2. 6.30 p.m. E. K. Wenlock: *Road Transport Law.*

Manchester Geographical Society, 16, St. Mary's Parsonage, Manchester, 3. 6.30 p.m. T. H. Oliver: *Some Italian Cities.*

Refrigeration, Institute of, at the Institution of Mechanical Engineers, Storey's Gate, S.W.1. 5.30 p.m. R. R. Poole: *The Influence of Mass Manufacture on Machine Design.*

WED. 18 MAR. Photographic Society, Royal, 16, Princes Gate, S.W.7. 7 p.m. Stuart Black: *The Trend of Pictorialism in the 20th Century.*

Victoria & Albert Museum, S.W.7. 6.15 p.m. Graham Reynolds: *John Constable.*

THURS. 19 MAR. Electrical Engineers, Institution of, Savoy Place, W.C.2. 5.30 p.m. *Economics in Wiring Practice* (Discussion).

Road Transport Engineers, Institute of, at the Royal Society of Arts, W.C.2. 6.30 p.m. J. H. Vincent: *Vehicle Maintenance from the Aspect of Safety.*

FRI. 20 MAR. British Sound Recording Association, at the Royal Society of Arts, W.C.2. 7 p.m. N. Leevers: *The Synchronisation of Magnetic Tape and Film for the Amateur and Professional.*

Mechanical Engineers, Institution of, Storey's Gate, S.W.1. 5.30 p.m. (1) J. H. Lamble and Salah E. A. Bayoumi: *A Room Temperature Photoelastic Technique for Three-dimensional Problems.* (2) J. D. C. Crisp: *The Use of Gelatin Models in Structural Analysis.*

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